UNIVERSITY OF CAPE COAST

EFFECT OF TEACHING AUTOMOTIVE ENGINEERING WITH COMPUTERS ON THE ACADEMIC PERFORMANCE OF STUDENTS

ISAAC ADAR MACCARTHY-DONKOR

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BY

ISAAC ADAR MACCARTHY-DONKOR

Dissertation submitted to the Centre for Continuing Education of the Faculty of Education, University of Cape Coast, in partial fulfillment of the requirements for award of Master of Education Degree in Information Technology.

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DECLARATION

Candidate's Declaration

I hereby declare that this dissertation is the result of my own original work and that no part of it has been presented for another degree in this university or else where.

Candidate's Signature……………………………….. … Date: ………………….

Name: Isaac Adar MacCarthy-Donkor

Supervisor's Declaration

I hereby declare that the preparation and presentation of this dissertation were supervised in accordance with the guidelines on supervision of dissertation laid down by the University of Cape Coast.

Supervisor's Signature…………………………… Date: ……………………….

Name: Dr. Jonathan A. Fletcher

ABSTRACT

This study was aimed at investigating the effect of computer assisted instruction as a supplementary strategy on the academic achievement of technical students offering Automotive Engineering Programme. It was a quasi experimental study and the purpose was to see the relative effectiveness of independent variable, (teaching strategy) on the academic performance of students in Automotive Engineering. Technical students pursuing Automotive Engineering Programme constituted the population for the study. Form 2 Automotive Engineering students from the Cape Coast Technical and the Kumasi Technical Institutes were selected as sample for the study. Students from the Cape Coast Technical Institute constituted the control group while their counterparts in the Kumasi Technical Institute formed the experimental group. Final data for analysis was collected from 40 students, 20 from each group. Significance of the difference between the mean scores of both groups on the variable of pre-test and post-test were tested at 0.05 level by applying *t*-test. The analysis of the pre-test showed that the *t*-value was -0.157 (Sig. 2-tailed = 0897) signifying that there was no significant difference between the two groups. However analysis of post-test data revealed that the *t*-value was 5.125 (Sig. 2-tailed = 0.000) showing that there was a significant difference between the two groups in favour of the experimental group. The study recommended that computer resources should be made available to schools and institutions that run practical oriented programmes so that students can learn and practise through simulations and other interactive software.

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DEDICATION

To my children

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CHAPTER ONE

INTRODUCTION

Background to the Study

All over the world, new technologies have been welcomed as a ready solution to many of the issues faced by management of school administrations. First and foremost, Information and Communications Technology (ICT) has become a vital part of the market ‘branding’ of higher education institutions, bestowing a hi-tech veneer onto educational institutions' often low-tech practices. The use of computer-based and computer-assisted teaching is seen to increase and ease educational institutions' processing of students, without demanding additional investment in costly physical resources such as classrooms or staff.

Prahalad and Hart (2002) considered that information poverty may be the single biggest roadblock to sustainable development. Commentators from diverse political persuasions are convinced that ICT offers a potentially valuable tool for development (Annan, 2001; and Ya’u, 2004). Appropriate use of ICT could enhance many aspects of life in developing countries from health to education to economic growth. Education is one area where ICT deployment and improved access to information promises to deliver tangible benefits. According to Steinberg (1991), ICT lends itself to adopting a more people or learner-centred approach to education. Freire’s liberation theory (1970) stresses the importance of a dialogical approach to education. ICT can facilitate a pedagogical shift entailing an educational interaction between teachers and learners. ICT, if used correctly, can encourage and support a meaningful two-way, informational flow between teachers and learners, moving away from the old behaviourist method of teaching where knowledge is simply transferred from teacher to student without any space for critical analysis on the part of the learner. Using ICT in education to produce ICT-literate students and a versatile, adaptable workforce is also consistent with the human capital theory of education. Hawkins (2002) states that, workers must learn how to learn and quickly acquire new skills. Augmenting the skills of the workforce in this way has the potential to benefit the economy at large and also improve the individual student's earning and employment potential.

Generally, the following functions of the use of ICT in education are described in literature (SER, 1998, Moonen and Kommers, 1995, Pilot, 1998):

1. ICT as object. It refers to learning about ICT. Mostly organized in a specific course. What is being learned depends on the type of education and the level of the student. Education prepares students for the use of ICT in education, future occupation and social life.
2. ICT as an 'assisting tool'. ICT is used as a tool, for example while making assignments, collecting data and documentation, communicating and conducting research. Typically, ICT is used independently from the subject matter.
3. ICT as a medium for teaching and learning. This refers to ICT as a tool for teaching and learning itself, the medium through which teachers can teach and learners can learn. It appears in many different forms,

such as drill and practice, tutorials, exercises, in simulations and educational networks.

4. ICT as a tool for organisation and management in schools.

ICTs can play a significant role in providing lecturers and students with access to educational content and up-to-date resources. The issues arising from the preceding paragraphs lead to the conclusion that education is one of the most important elements for achieving development success. However, ICT in turn can contribute towards enhancing education. This relationship was succinctly summarised by Kofi Annan (United Nations, 2003) when he asserted that:

> "While education unlocks the door to development, increasingly it is information technologies that can unlock the door to education".

Studies in the realm of individual learning have frequently demonstrated that the most effective teaching processes are those that rely heavily on constructive practices to motivate individuals. Since motivation has been recognized as a crucial factor in the learning process, it is naturally logical to apply the knowledge we have about motivation to one of the more contemporary and most promising modes of education, instruction via computer, or Computer-Assisted-Instruction (CAI). An important factor in motivation and CAI is self-determination. Deci and Ryan (1985) address the importance of self-determination (or choice) in intrinsic motivation. More recent research suggests that choice is an important factor in CAI as well (Kinzie, Sullivan, & Berdel, 1992; Yang & Chin, 1996).

Statement of the Problem

"Computer Assisted Instruction" (CAI) refers to instruction or remediation presented on a computer. Many educational computer programs are available online and from computer stores and textbook companies. They enhance teacher instruction in several ways.

Computer programs are interactive and can illustrate a concept through attractive animation, sound, videos and demonstration. They allow students to progress at their own pace and work individually. Computers provide immediate feedback; enabling students know whether their answer is correct. If the answer is not correct, the program shows students how to correctly answer the question. Computers offer a different type of activity and a change of pace from teacher-led or group instruction.

Students in Ghanaian Technical Institutions offering Automotive Engineering Programmes often find it difficult answering questions relating to principles of operation of most units and components of the motor vehicle. This could be attributed to the fact that, most of the units are enclosed and therefore very difficult and most a times impossible to visualize the operations of these units. For example, it is impossible to visualize what goes on in the combustion chamber of the internal combustion engine when the engine is running. Situations like these make it difficult for many students to understand the concepts pertaining to operations of many units and components of the vehicle. The traditional method of teaching Automotive Engineering by chalk-and-talk and workshop practice methods do not enable the student to understand most of the underlining operating principles of the motor vehicle.

Most available text books attempt to explain the operating principle of mechanisms and systems of the motor vehicle; however these text books are unable to print clear and vivid moving pictures of the various inter-linking components that support the operation of the motor car. For example, in describing the operation principle of the internal combustion engine, most text books describe the action of the piston and valves or ports with little or no mention of the connecting rod and the crankshaft. How the valves are operated and operations of the connecting rod and crankshaft are treated in isolation in many cases. This makes it difficult for most students to understand the relative motions among these basic components of the internal combustion engine: piston, crankshaft, connecting rod and the valves. Hence many students find it a big deal to determine relative positions of the above-mentioned components while in operation.

Slide and opaque projectors have also been used over the years to improve upon the mode of presentation of study materials to students. The slide projector is effectively able to project text, symbols and pictures from a prepared slide onto the screen, facilitating group discussions; it is unable to transmit moving pictures that could be used to foster students’ understanding of pertinent issues in the study of Automotive Engineering. The opaque projector, much like the slide projector, is unable to transmit moving pictures. The opaque projector only transmit text, symbols and still pictures from books and other opaque materials onto the screen. While this helps the teacher or instructor to effectively present learning materials to larger group of people, it is not possible to employ this tool to support teaching strategies such as drills, simulations and multimedia.

In view of the afore mentioned learning difficulties experienced by students in the Automobile industry, the researcher would like to investigate if the use of CAI in the form of tutorials, drills, videos and web-based simulations could improve the academic performance and understanding of students.

Purpose of the Study

The purpose of this study was to find out the relative effectiveness of using CAI as supplementary teaching strategy on the academic achievement of students in Automotive Engineering. It was also to find out how CAI could be used to help students understand some concepts in the study of Automotive Engineering Programmes.

Objective of the Study

The main objective of the study was to ascertain the effectiveness of Computer Assisted Instruction as supplementary teaching strategy, which could be used to support the teaching and learning of Automotive Engineering.

Hypothesis

To achieve the objective of the study, the following null hypothesis (H_0) were tested:

Is there a significant difference in students' achievements when they are taught using the traditional method or CAI supplement? The relevant null and alternative hypotheses were:

1. H_0: There is no significant difference between the mean scores of students taught Automotive Engineering with CAI as supplementing strategy and those taught without CAI.

2. H_1: There is significant difference between the mean scores of students taught Automotive Engineering with CAI as supplementing strategy and those taught without CAI.

Significance of the Study

The study is significant since its findings and conclusions could:

1. Encourage teachers to adopt or discourage them from adopting CAI as an appropriate approach for instructions in Ghanaian Technical Institutions.
2. Provoke further studies into the use of CAI as instructional strategy in Ghanaian Technical, and other Institutions.
3. Contribute to knowledge in the area of Automotive Engineering

Delimitation of the Study

The study is delimited to Cape Coast Technical Institute in the Central Region and the Kumasi Technical Institute in the Ashanti Region. Only second year Automotive Engineering students were used for the study. The topics treated were delimited to basic chassis and internal combustion engine-basics.

Limitations of the Study

The main limitation of the study is that, it has limited external validity. This is because the sample was purposively chosen and may not be representative of all Technical Schools in the country. It is therefore important to emphasise that the findings of the research and the conclusions drawn from the study can only accurately apply to classes in the schools which took part in the study. Using intact classes also meant that the groups were not equivalent as the pre-test indicated that the control group were less homogeneous than the experimental group, albeit the statistical test showed no significant difference between the mean scores of the groups. Finally, although the pre and post tests were validated by experts in the field of Automotive Engineering and ICT, the test items may not have measured achievement accurately. In spite of these limitations, every effort was made to ensure that the recording of the test scores was as accurate as possible.

Organisation of the Rest of the Study

The study is composed of chapters one through to chapter five. Chapter one discusses the background to the study, defines the problem and states the objective, purpose and significance of the study. It also states the hypothesis to be tested for the study. The chapter two, Literature Review, reviews related literature and works of other writers. Chapter three, Research Methodology, discusses the research design, population for the study and sampling. It also discusses the research instrument, data collection and methods used in analysing the data obtained. The fourth chapter is devoted to discussing the analysed data to make meaning out of it. Chapter five gives overview of the study, findings, recommendations and suggestions emanating from the result.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

This chapter reviews works of other writers which relate to the study. This review includes discussion on:

1. What is Computer Assisted Instruction (CAI)?
2. Historic overview of Computer Assisted Instruction.
3. Characteristics of Computer Assisted Instruction.
4. Computer Assisted Instruction and Learning Theories.
5. Ways in which CAI can support the teaching and learning of Automotive Engineering.
6. CAI and Learner Motivation.
7. Research works on Computer Assisted Instruction.

What Is Computer Assisted Instruction (CAI)?

The Association for Education Communication Technology (1977) has defined Computer –Assisted Instruction (CAI) as a method of instruction in which the computer is used to instruct the student and where the computer contains the instruction which is designed to teach, guide, and test the student until a desired level of proficiency is attained. “Computer Assisted Instruction” also refers to instruction or remediation presented on a computer. Others see CAI as a means of instructing students in all subject areas. Information and messages are presented to the learner using the computer, through interactive process involving drill practice, tutorial and dialogue. The CAI ensures that students are presented material or problems situations, guiding students' thinking, responding to students' questions, assessing students' performances and managing students' path through a course, (Milner and Anderson 1984).

Frenzel (1980) sees CAI as the process by which written and visual information is presented in a logical sequence to a student by a computer. The computer serves as an audio-visual device. The student learns by reading the text material presented or by observing the graphic information displayed.

Munden (1996) sees CAI as an educational medium in which instructional content or activities are delivered by a computer. Students learn by interacting with the computer and appropriate feedback is provided. Poole (1995) defined Computer Assisted Instruction as a computer based system designed to help students learn subject matter of all kinds.

Locatis and Atkinson (1984) describe Computer Assisted Instruction as a mode of instruction that involves student interaction with the computer directly. Typically, students access program presented in segments, with each segment including information and questions or problems for student's response. The correctness of each response is indicated immediately and remedial or new information is presented. Roblyer and Edwards (2000) defined CAI as a software designed to help teach information and/or skills related to a topic, also called courseware.

In the view of Steinberg (1991), CAI is a computer presented instruction that is individualized, interactive and guided. He opines that CAI is not a method of instruction. Many methods are implemented in it, including direct and exploratory lessons, drills, games and simulations.

All the cited definitions and views of Computer Assisted Instruction agree that the computer serves as a tool for delivering instructions in the form of tutorials, drills and practice, simulations and others.

Historical Overview of Computer CAI

Hall (1971) stated that the original attempts to automate instruction were initiated by Sidney Pressey in the early 1900s and by B. F. Skinner in 1954. He further stated that both Pressey and Skinner developed techniques of administering instructional materials to students by means of teaching machines or programmed text. The programmed text and teaching machines were very limited in their ability to become accustomed to individual differences among students or to offer a stimulating, responsive environment for students.

According to Suppes and Macken (1978), members of the computer industry were also among the earliest to use Computer Assisted Instruction. In the late 1950s, the computer industry used Computer Assisted Instruction to train its own personnel by linking typewriters and teletypes terminals to computers. Instructional modules were presented to the learners who then responded with one-syllable responses. The programming language for these modules was complicated and quite difficult for lay people to learn. Because of the complexity of the programming language, ways of simplifying such programming were explored (Suppes & Macken, 1978).

By 1960, International Business Machines (IBM) had developed the first computer-assisted author language, Coursewriter I. Educators were then able to directly program their curriculum ideas into the system (Suppes & Macken, 1978). According to Hall (1971), one of the basic problems in the early development of Computer Assisted Instruction was that most systems were built around modified business computers and terminal devices.

In 1963, a Computer Assisted Instruction research project began at Stanford University in the United States of America (USA). The Institute for Mathematical Studies in the Social Sciences (IMSSS) at Stanford University developed an instructional mathematical program for elementary students. The first instructional program consisted of a tutorial curriculum in elementary mathematical logic. The program was developed and tested in the spring of 1964. The study consisted of 41 fourth graders who were given daily arithmetic drill-practice lessons in their classroom. These lessons were given on a teletype machine that was connected to the Institute's computer by telephone lines (Suppes & Macken, 1978).

Recognising the innovative accomplishments made by the computer industry in the late 1950s and early 1960s, “Farsighted educators began dreaming about a computer age in higher education” (Kulik, Kulik, & Cohen, 1980, p. 525). In 1966, IBM developed the first computer system specifically for instructional purposes, the 1500 Instructional System. Hall (1971) pointed out that, computer-assisted programs before the mid-1960s were built around modified business computers and terminals and were not suitable for instructional purposes. The programs and systems developed in the early 1950s and 1960s used an electric typewriter or a teletype terminal through which students received information from the computer. The student, in turn, transmitted information to the computer. After the development of the 1500

Instructional System, most systems utilised television screens as the major display for students. Students fed responses to the program or system by the use of a typewriter keyboard. The use of random-access audio, playback/record capability, and random-access image projectors, all under program control, accompanied more complete instructional systems (Hall, 1971).

During the 1960s the University of Illinois in the USA, engaged in a computer-assisted project, PLATO (Programmed Logic for Automatic Teaching Operations), in connection with Control Data Corporation and the National Science Foundation (Alderman, Appel & Murphy, 1978; Kulik, Kulik, & Cohen, 1980; Magidson, 1978; Suppes & Macken, 1978). PLATO was one of the largest and perhaps most sophisticated computer systems designed for education. This system supported approximately 1000 terminals at different locations within the United States and abroad and provided each site with access to a central library of lessons (Alderman et al., 1978; Kulik et al., 1980; Magidson, 1978; Suppes & Macken, 1978).

In 1972, the Mitre Corporation of Bedford, Massachusetts and C. Victor Bunderson and Associates at Brigham Young University developed the Time-Shared, Interactive, Computer-Controlled, Information Television (TICCIT).The TICCIT combined mini-computers and television receivers in an instructional system with the display capabilities of colour televisions. The aim of the TICCIT program was to provide a complete and independent alternative to entire college courses in selected subjects (Kulik et al., 1980; Suppes & Macken, 1978). Suppes and Macken (1978) noted that the purpose of the TICCIT system was to use mini-computers and television technology to deliver computer-assisted lessons and educational programs in English and mathematics to community college students. The TICCIT lesson was displayed on a colour television screen connected to a keyboard and a local computer where students could respond. One TICCIT system could serve 128 terminals (Kulik et al., 1980). Rota (1981) stated the TICCIT system lessons were developed and designed by an assembled team of experts; whereas, the PLATO lessons were designed by teachers.

According to Rota (1981), the PLATO and TICCIT projects succeeded in introducing effective computer-assisted systems into schools. Each project led to the development and reliable operation of computer systems dedicated to instruction. The PLATO system supported hundreds of active terminals, and it gave each site a powerful tool for teaching. The TICCIT system had the display capabilities of television and employed an innovative instructional design. Schools accepted these systems as additional resources for promoting student learning and as a part of the approved curriculum.

In addition, Kulik et al (1980) stated that the evaluations of PLATO and TICCIT gave educators additional perspectives on computer-based college teaching and demonstrated that this teaching approach would be accepted in institutions of higher education as an additional resource for promoting student learning.

According to Rota (1981), the PLATO and TICCIT systems opened the gateway in the potential of a technology market in education. In addition, these two college-based, teaching programs were but two of many approaches that followed.

In the early 1970s, Computer Assisted Instruction was being implemented in different ways. A unique Computer Assisted Instruction program, Computer-Assisted Remediation and Evaluation (CARE), was designed to help classroom teachers identify children with particular mental handicaps that would adversely affect their academic progress. The CARE project was a self-contained college level course. The special feature of this Computer Assisted Instruction program was the method of dissemination. A mobile CAI unit was driven to teachers who requested the program. By 1972, the unit served teachers in Maryland, Pennsylvania, Texas, and Washington, D.C. (Suppes & Macken, 1978).

In 1975, the Computer Curriculum Corporation (CCC) was developed to offer a large variety of courses for elementary through junior college students. The CCC CAI system consisted of an instructional computer that provided individualized lessons to as many as 96 teletype terminals simultaneously. The computer and terminal were located at the school site, and neighbouring sites were then linked to the computer via telephone lines (Suppes & Mackens, 1978).

Mastery Learning Models

Two more worth mentioning development, parallel to the TICCIT were Program for Learning in Accordance with Need (PLAN), developed at the American Institute for Research and the Individually Prescribed Instruction (IPI) system at the University of Pittsburgh. These programs focused on using computer system to support mastery learning models with computer managed instructions system. IPI focused on diagnosis and development of curriculum materials in reading and arithmetic (Roblyer & Edwards, 2000).

Microcomputers in Schools

The first microcomputer came into schools in 1977 in the United States of America and focus rapidly shifted from mainframes to microcomputer systems (Roblyer & Edwards, 2000). This shift in hardware technology transformed the computer's role in education. As microcomputers gained popularity, a new software market for education driven primarily by teachers emerged. Computer resources and their instructional applications were no longer controlled by large companies or school district offices. Classroom teachers could decide what they wanted to do with computers (Roblyer & Edwards, 2000; Allessi & Trollip, 1991; Campbell, 2000). The availability of relatively inexpensive computers revived the dream when Commodore Business Machine (CBM) one of the first personal computer manufacturers, introduced commodore pet and commodore 64 in the late 1970s. These computers were widely used in schools. Later the Apple, Atare, Tandy and Radioshah computers invaded the classrooms (Campbell, 2000). Thereafter advancement in hardware and software technologies has improved tremendously paving way for application of computers in all spheres of life including education.

According to Schifter (2008), in the early 1980s, the programming language LOGO was developed by Seymour Papert to teach computer science concepts. She continues to explain that, at this time very little educational software was available. Most teachers didn't have access to a computer, and very few knew how to operate them. As computer technology became more prominent in the business world, it became obvious that students needed to become computer literate, which meant learning computing languages such as LOGO and BASIC. In 1983, the National Commission on Excellence in Education (NCEE) in the USA recommended computer science as one of five new requirements for high school graduation.

For the next few years, computer use was limited to teaching computer literacy in secondary schools in a computer lab with one teacher. She further writes that most other teachers didn't know how to use the computers and students didn't use them in other subjects. Software was developed for elementary students to quiz on facts or perform simple math drills, for example, but not for higher-level thinking activities. According to Shifter (2008), Apple II Computers found widespread acceptance in education in 1983, and Apple developed computer-based tutorials and learning games. In 1984, the Apple Works suite was introduced and featured word processing, spreadsheet, database, paint and drawing applications. This new software could be used by students in a variety of subjects, such as typing essays, organizing data and illustrating work.

In the early 1990s, laserdiscs emerged, and textbook companies often paired books with laserdiscs featuring video clips, images or diagrams to accompany material. By this time, high school typing classes transitioned from typewriters to computers. According to Shifter (2008) schools started using the Internet widely in 1995, and the following year, new graphics and multimedia tools were developed for delivering information and instruction using the Internet. Soon, schools in the USA began rewiring for Internet access.

Since the early 1980s, statistics show that computer usage in schools has grown remarkably. Schifter (2008), writes that the percentage of American schools with at least one computer rose from 18 percent in 1981 to 95 percent in 1987. In 1983, 40 percent of elementary schools and 75 percent of secondary schools used computers for instruction. By 1985, 1 million schools had computers. By 1995, there were 5.8 million computers in schools in the U.S. In 2003, 100 percent of American schools had access to the Internet. She again writes that, although the access to computers has risen sharply, the time most students spend on computers at school hasn't changed much, since their primary access is still in computer labs or libraries. The No Child Left Behind education mandates of 2001 requires all students in the USA to be computer literate by the eighth grade.

Schifter (2008) further explains that from the 1990s up to-2007, the growth of the internet has expanded far faster than most predicted. It soon became the world's largest database of information, graphics, and streaming video making it an invaluable resource for educators; but marketing-oriented web pages, computer viruses hidden within downloadable programs and/or graphics, and spam (widely disseminated email-based sales pitches) threaten its usefulness. Search engines such as Google and Yahoo constantly develop new ways to find information within the ever-growing number of web pages. Web sites that offer individuals a place to put personal information became popular, as did internet-based publishing and discussion forums. Voice recognition slowly enters the computing mainstream, but it's development is slowed by an unacceptable frequency of errors. Some computers incorporate TV input, but it is not as common as many predicted. Educational software becomes more useful and interesting to students as graphics and video are incorporated. Larger computer storage capacity and the growing prevalence of CD-ROM and DVD drives in personal computers make it easier for educators to store large graphic and video and sound files for educational applications. Lesson delivery over the internet has made distance education possible, moving students from the four-walled classrooms to experience learning at any time and any where.

The overview here tells of the evolution that CAI has gone through from the early 1900s to date. Recently, the use of technology in education and classroom teaching has increased across a variety of disciplines. In many cases, the use of multimedia instruction has been proven to be effective (Morrell, 1992; Rota, 1981; Kulik, Kulik, & Cohen, 1980).

Characteristics of Computer Assisted Instruction

This section discusses the makeup or the features of Computer Assisted Instruction (CAI). Computer Assisted Programs can be characterized by many attributes suitable to enhance learning. Some of the characteristics of Computer Assisted Instruction are discussed as follows.

Individualization

A computer program can provide multiple instructional paths, tailored to individualized needs (Steinberg, 1991). Students find multiple paths to proceed; every student finds an option to proceed according to his needs. Game format can add motivation and fantasy and maintain learner's attention. Concepts can be presented in tutorials with the aid of illustrative animation, dynamically creating illustrations and interspersing verbal explanations.

Simulations can provide new insights into relationships, or experiences that would otherwise not be possible.

Self Pacing

Self-pacing lets students proceed at a pace appropriate for their individual learning levels. Students using self-pacing can control the time allowed to solve problems as well as the rate of presentation, they can spend several weeks with remedial material or skip entire lesson. When they feel ready to be tested on a specific material, they can choose the testing cycle. Self-pacing helps to individualize instruction for those students who have used the program before or have prior knowledge of the subject matter. If Computer-Managed Instruction (CMI) is used, the system analyses the relationship between various factors pertaining to a student and suggests activities appropriate to individual students. This includes Program for Learning in Accordance with Needs (PLAN) and Individually Presented Instruction (IPI). In general student learn considerably well with CAI in considerably less time (Sampath, Panneerselvam and Santhanam, 1990).

Graphics, Text, Video and Sound

Computer Assisted Instruction makes use of multi-media software in the learning process including text, video technology, graphics, sound and internet technology. Computer Assisted Instruction is heavily used in the growing field of distance education. Traditionally, CAI, like programmed instruction, is linear in nature. Web-based instruction is however nonlinear (Lawson, 1999).

Flexibility

Flexibility here means access to teaching materials at a wide range of time or locations. Computers offer flexibility in the type of resources available to a student as well as increasing flexibility of access to information. Greater flexibility in education is one strategy for dealing with increased number and diversity of students. Computer programs can allow the user to choose from a variety of instructional treatments. Learning materials are presented in a variety of ways to suit students with differing learning styles. Instructional programs may use a variety of prompts and cues to produce correct student responses (Maier, Barnett, Warren and Brunner, 1998).

Methods Implemented in CAI

In the view of Steinberg (1991), CAI is a computer presented instruction that is individualized, interactive and guided. He opines that CAI is not a method of instruction. Many methods are implemented in it, including drills and practice, Tutorial, games and simulations.

Drill and Practice

Much of what we learn requires reinforcement and practice before it automatically becomes part of the way we do things. Learning, application, feedback and remediation are essential elements of the education cycle.

Drill and practice programs are used to provide repetitive exercise for rote skills that have been taught some other way. It is not the function of drill and practice software to impart instructional activities; rather, drill programs are useful for sustaining, refining or perfecting performance in some category of behaviour already learned by another method. Usually drill and practice is employed to increase the speed of accuracy of student performance of certain task. Software for drill and practice allows students to work problems or answer questions and get feedback on correctness. Computer aided drills provide endless practice of clearly defined skills. The student is given immediate feedback and when responses are inaccurate corrective action is immediately instituted. This process can be repeated effortlessly until the skill is learned appropriately. It is an important learning technique for building basic knowledge and basic intellectual skills, such as number manipulation, vocabulary, spelling sentence construction and others.

Drill and practice is typically associated with behaviourism, because students are commonly given ‘stimuli’ (questions), are required to make responses to the stimuli, and they receive some sort of reinforcement (Hsu, Chen & Hung, 2000).

Tutorials

Tutorials act like tutors by providing all the information and instructional activities a learner needs to master a topic. Tutorials, when designed effectively, can model the very best in teaching techniques. Tutorials can teach information, verify information and reinforce information through a process of interaction with the computer. Tutorials are best used to present new information (concepts and skills) to students. In many instances instruction is designed to be self-contained so that the student will have been thoroughly informed regarding the skills or knowledge under discussion. All the conceptual or skill based body of knowledge is presented on screen followed by quiz to assess the user’s comprehension of the concept or acquisition of skills. The software monitors the progress on the basis of the result of the quiz taking the learner onto a new material or back over old material; i.e mastery is required before learner is directed onto new learning material.

A good tutorial presentation is enjoyable, thorough, and sensitive to the user capabilities; and provides immediate feedback. Cox (1995) is of the view that, interactivity is key to user involvement and perseverance.

Tutorial software is more associated with the cognitive learning theory, because new knowledge is presented in a systematic way. It is expected that students learn principles and rules, comprehend them and become able to apply the newly acquired knowledge to new situations. A computer based tutorial program works with an individual student in a very interactive manner and often provides and ideal learning situation for information transmission (Hsu, Chen & Hung, 2000).

Application of Tutorial

Good tutorials should include presentation and guidance. They are used in almost all subject areas from the humanities to the social and physical sciences, and are appropriate for the presentation of factual information, for learning rules and concepts, and for learning problem solving strategies.

Software for Simulations

Simulations are powerful techniques that duplicate or replicate complex real life situations. Learners learn about the real world. Learning is made easier because simulations often simplify reality or they make learning more cost effective and safe. The major implication for learning with simulations is that the learner actually performs activities that are similar to those in reality. Simulations involve the learner in an explicit experience, of events or processes, representing the real situation. As such they marry nicely into a constructivist philosophy of teaching. Students experience life vicariously through the simulation, constructing knowledge about the world from that experience (Roblyer & Edwards, 2000).

Simulation provides a means of learning about an environment that may otherwise not be available to learner to explore, for reasons of safety, time, expanse, or general practicality. A simulation focuses on exploration and discovery learning. It is not an exercise that necessarily has a fixed or correct solution, and the route to the solution may be varied. Simulations afford the student the opportunity to explore relationships while allowing the learner to directly manipulate variables in the model. Although simulation programs are usually constructivist, i.e. they allow students to construct their own knowledge; they can have cognitive orientation also (Cox, 1995). Alessi & Trollip (1991) identify two main types of simulation:

1. Those that teach about something.
2. Those that teach how to do something.

Simulations that teach how to do something are classified either as procedural or situational simulations. Those that teach about something are classified either as physical or process simulations.

Procedural simulations teach a sequence of events that amount to a procedure. The primary objective is to teach the student how to do something. The student is presented with the symptoms and must follow a set of procedures to solve the problem. There may be more than one preferred procedure but the strength of a good procedural simulation lies in its ability to explore different avenues and their effects. They include diagnostic programs, in which students try to identify the sources of medical or mechanical problems, and flight simulators, in which students simulate piloting an airplane or other vehicle (Roblyer & Edwards, 2000).

Situational simulations deal with attitudes and behaviours of people in different contexts. This type of simulation allows the student to explore the effects of different approaches to a problem. The student plays the major role in solving the problem. Some simulations allow for various successful strategies such as letting students play the stock market or operate businesses. Others have most desirable and least desirable options such as choices when encountering a potentially volatile classroom situation (Roblyer & Edwards, 2000).

Physical simulations present a physical object or phenomenon on the computer screen, giving the student an opportunity to learn about it. An example is the observation of molecules under influences of temperature and pressure. The learner is able to manipulate extraneous variables in order to see effect. This type of simulation presents opportunities for the learner that would not normally be available. For example students see selections of chemicals with instructions to combine them to see the result or they may see how various electrical circuits operate (Roblyer & Edwards, 2000). Time and size do not limit the capabilities of the simulation.

Process simulations also teach about something. They are normally used to demonstrate processes that are not overtly visible like the economic law of supply and demand, and how populations grow and decline. Biological simulations like those on genetics are popular, since they help student experiment by pairing animals with given characteristics and showing the resulting offspring (Roblyer & Edwards, 2000). Process simulations are used for forecasting these types of situations. They are useful because they can also accelerate or slow down these processes.

Computer Assisted Instruction and Learning Theories

Learning is a complex phenomenon. There are many different types of learning, ranging from the very simple response of touch to the type of thought that results in the solution to a complex scientific problem. There seems to be disagreement over what learning actually is. This originates from the fact that different theorists hold differing views on how learning takes place. This section of the write-up discusses the origin of the various theories and their relationship to learning as well as CAI.

What is a Theory?

Dorin, Demmin & Gabel (1990) explain theory as that which

1. Provides a general explanation for observations made over time.
2. Explains and predicts behaviour.
3. Can never be established beyond all doubt.
4. May be modified.
5. Seldom have to be thrown out completely if thoroughly tested but sometimes a theory may be widely accepted for a long time and later disproved.

There are three main type of theories associated with learning. According to Schuman (1996), they are:

1. Behaviourism - Based on observable changes in behaviour. Behaviourism focuses on a new behavioural pattern being repeated until it becomes automatic.
2. Cognitivism - Based on the thought process behind the behaviour. Changes in behaviour are observed, and used as indicators as to what is happening inside the learner's mind.
3. Constructivism - Based on the premise that we all construct our own perspective of the world, through individual experiences and schema. Constructivism focuses on preparing the learner to solve problem in ambiguous situations.

The Origin of Behaviourism

Behaviourism, as a learning theory, can be traced back to Aristotle, whose essay "Memory" focused on associations being made between events such as lightning and thunder. Black (1995) writes that, other philosophers that followed Aristotle's thoughts are Hobbs (1650), Hume (1740), Brown (1820), Bain (1855) and Ebbinghause (1885).

The theory of behaviourism concentrates on the study of overt behaviours that can be observed and measured (Good & Brophy, 1990). It views the mind as a "black box" in the sense that response to stimulus can be observed quantitatively, totally ignoring the possibility of thought processes occurring in the mind. Behaviourists emphasized that progress was to be made in scientific study of human or animal mental functions and behaviours only through the elimination of such research topics as memory and mind while concerning oneself solely with observable phenomenon – behaviour. This concept was introduced by John Watson, and shortly stimulus-response (S-R) psychology became the American tradition.

Pavlov and Classical Conditioning

Pavlov was a Russian physiologist who is best known for his work in classical conditioning or stimulus substitution. Pavlov's most famous experiment involved food, a dog and a bell.

Pavlov's Experiment

1. Before conditioning, ringing the bell caused no response from the dog. Placing food in front of the dog initiated salivation.
2. During conditioning, the bell was rung a few seconds before the dog was presented with food.
3. After conditioning, the ringing of the bell alone produced salivation. (Dembo, 1994).

Other Observations Made by Pavlov

1. Stimulus Generalization: Once the dog has learned to salivate at the sound of the bell, it will salivate at other similar sounds.
2. Extinction: If you stop pairing the bell with the food, salivation will eventually cease in response to the bell.
3. Spontaneous Recovery: Extinguished responses can be "recovered" after an elapsed time, but will soon extinguish again if the dog is not presented with food.

4. Discrimination: The dog could learn to discriminate between similar bells (stimuli) and discern which bell would result in the presentation of food and which would not.
5. Higher-Order Conditioning: Once the dog has been conditioned to associate the bell with food, another unconditioned stimulus, such as a light may be flashed at the same time that the bell is rung. Eventually the dog will salivate at the flash of the light without the sound of the bell.

Thorndike and the law of Effect

Thorndike is accredited with the development of the law of effect, emphasizing the importance of reward (reinforcement) in learning. Edward Thorndike a researcher in animal behaviour later became interested in human psychology. He set out to apply "the methods of exact science" to educational problems by emphasizing "accurate quantitative treatment of information". "Anything that exists, exists in a certain quantity and can be measured" Johcich, (cited in Rizo, 1991). His theory, Connectionism, stated that learning was the formation of a connection between stimulus and response.

1. The "law of effect" stated that when a connection between a stimulus and response is positively rewarded it will be strengthened and when it is negatively rewarded it will be weakened. Thorndike later revised this "law" when he found that negative reward, (punishment) did not necessarily weaken bonds, and that some seemingly pleasurable consequences do not necessarily motivate performance.

2. The "law of exercise" held that the more an S-R (stimulus response) bond is practiced the stronger it will become. As with the law of effect, the law of exercise also had to be updated when Thorndike found that practice without feedback does not necessarily enhance performance.
3. The "law of readiness”: because of the structure of the nervous system, certain conduction units, in a given situation, are more predisposed to conduct than others.

Thorndike's laws were based on the stimulus-response hypothesis. He believed that a neural bond would be established between the stimulus and response when the response was positive. Learning takes place when the bonds are formed into patterns of behaviour (Saettler, 1990).

J.B. Watson and Behaviourism

John B. Watson was the first American psychologist to use Pavlov's ideas. Like Thorndike, he was originally involved in animal research, but later became involved in the study of human behaviour. Watson believed that humans are born with a few reflexes and the emotional reactions of love and rage. All other behaviour is established through stimulus-response associations through conditioning.

Watson's Experiment

Watson demonstrated classical conditioning in an experiment involving a young child (Albert) and a white rat. Originally, Albert was unafraid of the rat; but Watson created a sudden loud noise whenever Albert touched the rat. Because Albert was frightened by the loud noise, he soon became conditioned to fear and avoid the rat. The fear was generalized to other small animals. Watson then "extinguished" the fear by presenting the rat without the loud noise. Some accounts of the study suggest that the conditioned fear was more powerful and permanent than it really was (Good & Brophy, 1990).

Skinner's Operant Conditioning Mechanisms

Later on in the history of behaviourism, Skinner proposed the concept of operant conditioning, in which even the stimulus (S) was removed from S-R, with only the response (R) followed by reinforcement forming the critical learning element. The following definitions are useful in the discussion of the S-R theory.

1. Positive Reinforcement or reward: Responses that are rewarded are likely to be repeated. (Good grades reinforce careful study.)
2. Negative Reinforcement: Responses that allow escape from painful or undesirable situations are likely to be repeated. (Being excused from writing a final examination because of good term work.)
3. Extinction or Non-Reinforcement: Responses that are not reinforced are not likely to be repeated. (Ignoring student misbehaviour should extinguish that behaviour.)
4. Punishment: Responses that bring painful or undesirable consequences will be suppressed, but may reappear if reinforcement contingencies change. (Penalizing late students by withdrawing privileges should stop their lateness.)

(Good & Brophy, 1990)

Over the years, Skinner's research was so well done and convincing that his views dominated the field of psychology (Chambers and Sprecher, 1983).

Criticisms of Behaviourism

Laudable as behaviourism might seem, it could not account for all issues relating to learning situations. Behaviourism does not account for processes taking place in the mind that cannot be observed. Chomsky (1962) argues on linguistic competencies; the capacity of the human mind to generate all and only the sentences of a given language. He further contents that "Nativism" is a view of language acquisition, which claims that language development is innate. This contradicts Skinner (1953) that behaviours can only be accounted for by external forces acting on the organism. Behaviourists also advocate for passive student learning in a teacher-centric environment, asserting that the teacher is all knowing and that pupils' minds should be seen as empty receptacles into which knowledge must be poured from the teacher to fill. They further advocate for the conformity of learners thereby ignoring individual differences in the learning process.

The Basics of Cognitivism

As early as the 1920's people began to find limitations in the behaviourist approach to understanding learning. As a result psychologist began to worry about lack of progress in understanding what many believed were fundamental problems in that field, involving cognitive events such as thinking, memory, perception, and mental process in general. The cognitive revolution became evident in American psychology during the 1950's (Saettler, 1990). One of the major players in the development of cognitivism is

Jean Piaget, who developed the major aspects of his theory as early as the 1920's. Piaget's ideas did not impact North America until the 1960's after Miller and Bruner founded the Harvard Center for Cognitive studies.

Key Concepts of Cognitive Theory

The following definition and summaries are relevant to the discussion of the cognitive theory:

1. Schema - An internal knowledge structure. New information is compared to existing cognitive structures called "schema". Schema may be combined, extended or altered to accommodate new information.
2. Three-Stage Information Processing Model - input first enters a sensory register, then is processed in short-term memory, and then is transferred to long-term memory for storage and retrieval.

    1.1 Sensory Register - receives input from senses which lasts from less than a second to four seconds and then disappears through decay or replacement. Much of the information never reaches short term memory but all information is monitored at some level and acted upon if necessary.

    1.2 Short-Term Memory (STM) - sensory input that is important or interesting is transferred from the sensory register to the STM. Memory can be retained here for up to 20 seconds or more if rehearsed repeatedly. Short-term memory can hold up to 7 plus or minus 2 items. STM capacity can be increased if material is chunked into meaningful parts.

1.3 Long-Term Memory and Storage (LTM) - stores information from STM for long term use. Long-term memory has unlimited capacity. Some materials are "forced" into LTM by rote memorization and over learning. Deeper levels of processing such as generating linkages between old and new information are much better for successful retention of material.

3. Meaningful Effects - Meaningful information is easier to learn and remember. (Cofer, 1971, in Good and Brophy, 1990) If a learner links relatively meaningless information with prior schema it will be easier to retain. (Wittrock, Marks, & Doctorow, 1975, in Good and Brophy, 1990)
4. Serial Position Effects - It is easier to remember items from the beginning or end of a list rather than those in the middle of the list, unless that item is distinctly different.
5. Practice Effects - Practicing or rehearsing improves retention especially when it is distributed practice. By distributing practices the learner associates the material with many different contexts rather than the one context afforded by mass practice.
6. Transfer Effects- The effects of prior learning on learning new tasks or material.
7. Interference Effects - Occurs when prior learning interferes with the learning of new material.
8. Organization Effects - When a learner categorizes input such as a grocery list, it is easier to remember.

9. Levels of Processing Effects - Words may be processed at a low-level sensory analysis of their physical characteristics to high-level semantic analysis of their meaning. (Craik and Lockhart, 1972, in Good and Brophy, 1990) The more deeply a word is processed the easier it will be to remember.
10. State Dependent Effects - If learning takes place within a certain context it will be easier to remember within that context rather than in a new context.
11. Mnemonic Effects - Mnemonics are strategies used by learners to organize relatively meaningless input into more meaningful images or semantic contexts. For example, the units of linear measure can be remembered by the rhyme: My Car Dropped Me Down Here.
12. Schema Effects - If information does not fit a person's schema it may be more difficult for them to remember and what they remember or how they conceive of it may also be affected by their prior schema.
13. Advance Organizers – Asubel’s advance organizers prepare the learner for the material they are about to learn. They are not simply outlines of the material, but are material that will enable the student to make sense out of the lesson.

At about the time of developing cognitive concept, computers became prevalent in higher education. The emphasis on information processing concept which likened the operation of computers to the brain was accompanied by general social and professional acceptance of the value of such machine.

Criticisms of Cognitivism

Though cognitivism may be seen as a theory which provides meanings to all the processes involved in the teaching and learning process; it should however not be taken as a panacea that solves all problems related to learning. Cognitivism much like behaviourism, recommend that knowledge itself is given and is absolute. According to Schuman (1996) the goal of cognitivism is to train learners to do a task the same way to provide consistency. The learner learns a way to accomplish a task, but that way may not be the best, most efficient or safest way to do something in a different culture or environment. In addition, the idea that mental functions can be described as information processing models has been criticized by Searle (1980) who argues that, computation has some inherent shortcomings which cannot capture the fundamentals of mental processes.

The Basics of Constructivism

Bartlett pioneered what became the constructivist approach (Good & Brophy, 1990). Constructivists believe that learners construct their own reality or at least interpret it based upon their perceptions of experiences, so an individual's knowledge is a function of one's prior experiences, mental structures, and beliefs that are used to interpret objects and events. What someone knows is grounded in perception of the physical and social experiences which are comprehended by the mind (Jonassen, 1991).

The Assumptions of Constructivism

The following assumptions underpin constructivist practices.

1. knowledge is constructed from experience

2. learning is a personal interpretation of the world
3. learning is an active process in which meaning is developed on the basis of experience
4. conceptual growth comes from the negotiation of meaning, the sharing of multiple perspectives and the changing of our internal representations through collaborative learning
5. learning should be situated in realistic settings; testing should be integrated with the task and not a separate activity (Merrill, 1991).

These assumptions suggest that knowledge is accumulated through individual's experiences. Moreover learning should be contextual or should be related to solving real life situation.

Criticisms of Constructivism

Constructivism advocates that the individual construct his/her own understanding of the world, ignoring the fact that the individual needs to be equipped with some basic skills to enable the individual construct his/her understanding of the world. Gough and Hillinger (1980) argue that literacy is an unnatural act and as such training plays a far greater role in the learning process than it does for something with such a large biological contribution as language. The constructivists opine that the individual should be guided to develop his or her own way of doing things. Schuman (1996) suggests that in a situation where conformity is essential, divergent thinking and action may cause problems. In the school setting adopting constructivist view in its entirety may not fit well with traditional age grouping and rigid terms/semester programmes. Again since constructivists approach to instruction is less rigorous than the traditional approach; it becomes more difficult to obtain a uniform standard for assessing the performance of the various students.

Application of Learning Theories in CAI

All theorists agree that certain conditions must be fulfilled before learning could take place. These conditions include contiguity, reinforcement and repetition (practice). The basis for behaviourists' theory was that a stimulus (S) that elicited a response (R) that was immediately followed by positive reinforcement will result in increasing the probability that the response would be repeated upon further presentation of the stimulus. Thus the S-R reinforcement became the learning model. In this section of the write up the researcher would want to relate the various learning theories to CAI design and their applications to learning. Most of the discussions on behaviourism will dwell on Skinner's operant conditioning.

Skinner agreed with the contiguity principle, but emphasized the importance of immediate reinforcement following the response. He also stressed that students should be given task in a hierarchy so that they would learn essential components first, and so that they would not fail (Chambers and Sprecher, 1983).

Application of Skinner's Views to CAI

Skinner's views are directly applicable to drill and practice and tutorials forms of CAI. Reinforcement in drill and practice: skinner's main thesis is that positive reinforcement should consistently follow each occurrence of the desired response until the selected level of mastery is reached. Once mastery is attained, Skinner stressed that students must be weaned from this approach in order to avoid rapid extinction of the response. He thus recommended shifting from continuous reinforcement to a pattern of intermittent reinforcement. Skinner emphasized that through these methods, behaviour could be maintained indefinitely on a very small number of reinforcement. He concluded that through a proper understanding of contingencies of reinforcements, we should be able to make students eager and diligent and be reasonably sure that they will continue to enjoy the things we teach them for the rest of their lives (Skinner, 1968).

The course ware designed for this project incorporated a drill and practice programme which sought to give continuous reinforcement to learners until mastery is achieved. Once mastery has been attained, fixed-ratio and variable-ratio schedule of reinforcements are introduced ensure concretization of learnt material.

Application to Tutorials

Skinner's illustration of how to develop a programmed learning sequence is directly applicable to the design of CAI tutorial as follows:

1. Obtain a clear, detailed objective specification of what it means to know the given subject matter.
2. Write a series of information, question, and answer frame that expose students to the material in graded steps of increasing difficulty and that frequently retest the same facts from many different angles.
3. Require the learner to be active, (the programme should be interactive)
4. Provide immediate feedback for each answer (response).

5. Trial to arrange the material and questions in such a manner that the correct response is likely to occur and be reinforced.
6. Permit students to proceed at their own pace
7. Provide ample backup reinforcement for diligent and effective work.

Skinner's view on the role the teacher must play in the learning situation is that the best way to help the student give birth to the answer he is struggling to recall is to give him a strong hint or even the whole answer, but that is not the best way to make sure that he will recall it in future. As Comenius believed, the more the teacher teaches, the less the student learns; and the better the teacher, the more important it is that he frees the student from the need for instructional help (Skinner, 1968).

The application of these views on the importance of student control is especially helpful when considering the design and development of tutorials. In this type of learning situation, the computer plays the role of adviser, and the learning strategies involved are concerned with presentation of materials and questions, hints and help messages to assist the student as needed to achieve the correct answers, followed by reinforcement of the correct response.

Cognitive Theories and CAI

As discussed earlier, cognitive theories are based on information processing models. These are concerned with how individuals gain knowledge and how they use it to guide decisions and perform effective actions. These theories attempt to understand the mind and how it works. To achieve this, they view the computer as a model of the brain and employ much of the terminology and concepts of information processing.

According to Bower and Hilgard (1981), long-term memory (LTM) contains information originally held in the short-term memory (STM), which had gone through a process of semantic encoding. This process changes information from words and stimuli to schemes that have meaning and holds codes for retrieval at later times.

Though cognitive theory recognizes the importance of reinforcement, it does not give it the central importance accorded by skinner. It indicates that learner behaviour sets in motion a process that depends on external feed back, which involves confirmation of correct performances.

One of the important concepts in cognitive theories is the executive control process. This process controls cognitive strategies relevant to learning and remembering in relation to such important activities as:

1. Controlling attention.
2. Encoding of incoming information.
3. Retrieval of stored information.

The application of these to CAI is crucial, and this is the area where cognitive theory has made significant contribution to CAI.

In the view of (Gagne & Briggs, 1979), the following kinds of processing occur for any single act of learning:

1. Attention – Selection among incoming stimuli.
2. Selective perception – encoding selected items for storage in STM.
3. Rehearsal – maintaining data in STM.
4. Semantic encoding – preparing information for storage in LTM.

5. Retrieval – searching and restoring information in working memory.
6. Response organization – selecting and organizing performance.
7. Feedback – the external event that sets in motion the process of reinforcement.
8. Executive control process – selecting and activating cognitive strategies.

Gagne's Theory of Instruction

1. Both Bloom and Gagne believed that it was important to break down humans' learned capabilities into categories or domains. Gagne's taxonomy consists of five categories of learning outcomes - verbal information, intellectual skills, cognitive strategies, attitudes, and motor skills. Gagne, Briggs, and Wager (1992) explain that each of the categories leads to a different class of human performance.
2. Essential to Gagne's ideas of instruction are what he calls "conditions of learning." He breaks these down into internal and external conditions. The internal conditions deal with previously learned capabilities of the learner. Or in other words, what the learner knows prior to the instruction. The external conditions deal with the stimulus (a purely behaviourist term) that is presented externally to the learner.
3. To tie Gagne's theory of instruction together, he formulated nine events of instruction. When followed, these events are intended to promote the transfer of knowledge or information from perception

through the stages of memory. Gagne bases his events of instruction on the cognitive information processing learning theory.

Application of Cognitive Theories in CAI

Cognitive learning theories are most applicable to the design and development of tutorials. This approach has been pioneered most actively by Robert M. Gagne, a former follower of Skinner and the behaviourist model. Gagne has stressed the importance of identifying the goals of the learning task followed by the development of specific instructional objectives to meet these goals. He emphasizes that such objectives must be stipulated in concrete behavioural terms. Thereafter the skill level of the learner must be assessed and programmes designed to teach the skills.

Gagne followed Skinner's way of developing and presenting materials, stressing that learning must occur in small steps, sequenced so that lower level learning required for performance on more complex task is learnt first. Further more, just like Skinner; Gagne has emphasized the use of positive reinforcement in a repetitive approach.

With regard to the role of the teacher or adviser in CAI, Gagne agrees with Skinner by emphasizing that hints and help needs to be adapted to the individual learner. Gagne has suggested that students be provided with a little help at a time, thus permitting the student to use as much as he needs. The student is thus placed in control of the learning situation. So far as mastery is concerned, Gagne has expanded Skinner's basic views on the topic to include more details related to human learning. He has defined mastery as materials that have been learned to the level of which they are readily accessible to recall at the time of learning.

Gagne's most significant contribution, however, relate to his application of cognitive theory to the task of designing CAI modules. Thus, he has brought to the topic some additional insights and emphasis, such as his concern with gaining the attention of the learner and developing expectancies. This can be achieved in CAI modules by providing advance organizers in the instruction. These organizers might take the forms of charts or graph that reflect the structure and organization of the lesson content.

Another point raised by Gagne is in defence of drill and practice, he indicated his belief that drill and practice, if viewed as cognitive learning theory, simply speeds up the learning process, that it makes learning more efficient by making lower level skills automatic. Since such skills are used quite often, and since STM has a limited capacity, drill and practice reinforces the indexing characteristics of the basic skills, thus permitting them to be retrieved and placed in STM for use very quickly (Gagne, 1982).

Constructivism and CAI

Constructivism as described earlier is a theory based on observation and scientific study about how people learn. It postulates that people construct their own understanding and knowledge of the world, through experiencing things and reflecting on those experiences. When a learner encounters something new, he has to reconcile it with his previous ideas and experience, this may result in changing what he believes, or discarding the new information as irrelevant. In any case, we are active creators of our own knowledge. To do this, we must ask questions, explore, and assess what we know.

In the classroom, the constructivist view of learning can point towards a number of different teaching practices. In the most general sense, it usually means encouraging students to use active techniques (experiments, real-world problem solving) to create more knowledge and then to reflect on and talk about what they are doing and how their understanding is changing. The teacher, serving as a facilitator, makes sure he understands the students' pre-existing conceptions, and guides the activity to address them and then build on them.

Constructivist teachers encourage students to constantly assess how the activity is helping them gain understanding. By questioning themselves and their strategies, students in the constructivist classroom ideally become "expert learners." This gives them ever-widening tools to keep learning. With a well-planned classroom environment, the students learn how to learn.

Since learning by the constructivist approach is not guided by specified goals, instructional objectives (is unstructured) and method of assessing the terminal behaviour, it is some what complicated in designing a courseware from the constructive approach. One of the most useful tools for the constructivist designer is hypertext (text which contains links to other texts) and hypermedia (hypertext which is not constrained to be text: it can include graphics, video and sound) because it allows for a branched design rather than a linear format of instruction. Hypertext allows for learner control which is crucial to constructivist learning; however, there are some concerns over the novice learner becoming "lost" in a sea of hypermedia. To address this concern, constructivists (Jonassen 1997; Kirschner, Sweller, & Clark, 2006), concede that each phase of knowledge acquisition requires different types of learning and that initial knowledge acquisition is perhaps best served by classical instruction with predetermined learning outcomes, sequenced instructional interaction and criterion-referenced evaluation while the more advanced second phase of knowledge acquisition is more suited to a constructivist environment.

Reigeluth and Chung (as cited in Davidson, 1998) suggest a prescriptive system which advocates increased learner control. In this method, students have some background knowledge and have been given some instruction in developing their own meta-cognitive strategies and have some way to return along the path they have taken, should they become "lost".

Most literature on constructivist design suggests that learners should not simply be let loose in a hypermedia or hypertext environment, but that a mix of old and new (objective and constructive) instruction/learning design be implemented. Davidson's (1998) article, suggesting a criteria for hypermedia learning based on an "exploration of relevant learning theories", is an example of this method.

Application of Constructivism in CAI

The implications of constructivism look most appropriate to promoting learning as that which occurs in the use of simulations in CAI. Although real models are not used in such simulations, the computer provides a reality situation in which the student may learn vicariously through interaction with the model. Since the constructivist approach to learning does not follow linear or structured instruction, it is of utmost importance that in designing learning package for constructivist learning situations; there should be inclusion of linkages, (hypertext and hypermedia) between different learning materials and situations. To promote interactivity, interactive multimedia (text, sound, pictures and video) is employed.

Backtracking Links

It is important that when a user is browsing in a hypertext document and uses links to other documents or other nodes in the same document that he should be able to return to the point he had reached in the original text, should he wish to do so. Failure to provide a means of return can leave the user "lost in Hyperspace".

According Agosti, Gradenigo and Mattiello (1990), one method of backtracking is to have a reference button back to a predetermined location e.g. the first screenful of related text. If there is a reference button from a summary of a presentation to a section of a tutorial, a reciprocal reference button could be provided back to the summary of presentation. This creates a very rigid structure and it is found that it ceases to be viable when there is a node in the network to which there are links from several different sources. It would be necessary to have a labelled reference button back to each possible departure node. They again contend that backtracking is possible using the "navigate" menu in guide, but the aim is for the students to learn the subject matter without having to learn to use the application software first. The system should be as intuitive as possible.

In a tutorial document clicking on a “backtrack” button or text navigates back automatically to whichever reference button was used as the departure point to reach the current node. In effect it is like locating a "bookmark" in the same way as if when reading a text book, the reader leaves a bookmark at the point he had reached whilst looking up another document. This differs from a "home" button which always returns the user to the top of the document the user is using, from where the learner has to navigate again to the point reached. This ability to have "soft" links generated by the students as they use the teaching material allows the hypertext system to be an extension of the way in which the student learns rather than every link being predetermined. It allows links to exist between several separate documents without causing an incomprehensible tangle of links.

Another method of learning postulated by constructivists is the experiential. In CAI hyperlinks are created in learning materials which links learner to videos and simulations of the material to be learned. In this way the learner learns by observing the video and creates his own knowledge about the subject matter through the observations that he makes. Having observed how a particular thing is done, he done applies the knowledge gained by trying his hands on simulations of the form suitable to the subject matter. For example, a “phase-check” programme could used to learn how components of a machine is assembled and dissembled.

From the discussion above, it could be realized that no single learning theory works best for all learning situations. Kirschner, et al. (2006) describe constructivist teaching methods as "unguided methods of instruction." They suggest more structured learning activities for learners with little to no prior knowledge. Sweller and his colleagues argue that novices do not possess the underlying mental models, or "schemas" necessary for "learning by doing" (Sweller, 1988). Undeniably, Mayer (2004) reviewed the literature and found that fifty years of empirical data do not support using the constructivist teaching technique of pure discovery; in those situations requiring discovery, he argues for the use of guided discovery instead.

After having compared and contrasted behaviourism, cognitivism and constructivism, Ertmer and Newby (1993) feel that the instructional approach used for novice learners may not be efficiently stimulating for a learner who is familiar with the content. They do not advocate one single learning theory, but stress that instructional strategy and content addressed depend on the level of the learners. Similar to Jonassen, they match learning theories with the content to be learned.

Ertmer and Newby (1993) believe that the strategies promoted by different learning theories overlap (the same strategy for a different reason) and that learning theory strategies are concentrated along different points of a continuum depending of the focus of the learning theory - the level of cognitive processing required.

To sum up the various theories and their application to CAI, Ertmer and Newby (1993), opine that a behavioural approach can effectively facilitate mastery of the content of a profession (knowing what); cognitive strategies are useful in teaching problem-solving tactics where defined facts and rules are applied in unfamiliar situations (knowing how); and constructivist strategies are especially suited to dealing with ill-defined problems through reflection-in-action.

Instructional designers must therefore allow circumstances surrounding the learning situation to help them decide which approach to learning is most appropriate. It is necessary to realize that some learning problems require highly prescriptive solutions, whereas others are more suited to learner control of the environment. (Schwier, 1995)

Ways in Which CAI can Support the Teaching and Learning of Automotive Engineering

The teaching of automobile engineering programme in Ghana has been characterized by the lecture method of teaching, followed by introduction of learners to the physical components making up the motor car. In some cases there are models to support student's learning by enabling the student to practice to some extent with these models. In the Cape Coast and Kumasi Technical schools where this research was conducted, there are both live and cross-sectioned components of the motor vehicle, which facilitate learning by enabling students to identify the various components and conceptualized their operating principles through interactions with these models.

However these methods of teaching automobile engineering do not enable learners to realize what actually happens in the enclosed components and systems making up the motor car. For example it will be extremely difficult if not impossible for a learner to visualize and conceptualize what occurs in the engine cylinder during the combustion process. In this regard CAI could be seen as useful tool which could be used to foster student's understanding.

Steinberg (1991), suggests that CAI is a computer presented instruction that is individualized, interactive and guided. He opines that CAI is not a method of instruction. Many methods are implemented in it, including drills and practice, Tutorial, games, videos, simulations, interactive-multimedia and others. In this section of the write up, the researcher would like to look at how these methods implemented in CAI, could be used to teach Automotive Engineering Programme.

The effectiveness of any teaching and learning activity depends on whether the activity is helping to attain the learning objectives. In a behaviourist learning environment, the learning can be quantified in terms of behaviour change and a change in behaviour of students occurs as a result of three domains of learning; cognitive, psychomotor and affective. In Automotive Engineering, cognitive domain learning is very important as it deals with imparting edifying information about knowledge and facts. The learning results in understanding learning objectives at an easy level to a more complex level, enabling knowledge transfer from very low level requiring memorisation and recall to very complex learning situations.

In learning Automotive Engineering, like all other programmes, certain basic facts and concepts need to be mastered before any meaningful learning can take place. These basics may include; names, functions, identification and operations of the various components making up the motor vehicle. In addition, the relationships between the various components and systems should be conceptualized to promote deeper understanding and applicability of what has been learnt.

For mastery of basic facts in Automotive Engineering, drill and practice and tutorials could be used to automate these in learners. After the learners have been taught the basic facts in Automotive Engineering by way of tutorials, drill and practice could be used to foster mastery of what has been taught. Drill and practice is typically associated with behaviourism, because students are commonly given ‘stimuli’ (questions), are required to make responses to the stimuli, and they receive some sort of reinforcement (Hsu, Chen & Hung, 2000).

For this research work, the researcher designed and used software which presented factual material through tutorials; this was followed by drill and practice which enabled the learners to master the subject matter. In Gagne's view, drill and practice, if viewed as cognitive learning theory, simply speeds up the learning process, that is it, makes learning more efficient by making lower level skills automatic. Since such skills are used quite often, and since Short Term Memory (STM) has a limited capacity, drill and practice reinforces the indexing characteristics of the basic skills, thus permitting them to be retrieved and placed in STM for use very quickly (Gagne, 1982).

In Automotive Engineering another domain of learning which is of interest to the researcher for the purpose of this paper is the psychomotor domain. The psychomotor domain of learning equips learners to do things in a particular way. The 'hands on' approach of learning is covered in this domain. There are a number of psychomotor skills that needs to be embedded in the learning objectives in a typical Automotive Engineering lesson. As with the other two domains of learning proposed by Bloom, for psychomotor learning domain taxonomy is based on the premise that the categories are ordered in degree of difficulty. In each learning domain the learner needs to master a category before mastering another category at a higher level. As such the categories within each domain are levels of learning development, and these levels increase in difficulty. In psychomotor domain the categories in the increasing order of difficulty are as follows:

1. Imitation **–** Copy action of another, observe and replicate

2. Manipulation – Reproduce activity from instruction or memory
3. Precision – Execute skills reliably, independent of help
4. Articulation – Adapt and integrate expertise to satisfy a non-standard objective
5. Naturalization – Automated, unconscious mastery of activity and related skills at strategic level

Abdulrassol and Mishra (1998), suggest that to teach psychomotor skills using Computer Assisted Instruction (CAI), video and sound technologies and simulations implemented in CAI could be used. Learners are given the opportunity to watch the video and observe how to do things in a particular way. These may include how to handle a particular tool and procedure for dismantling and assembling specific components. Having observed specific activity overtime, simulations could then be used as an attempt for the learner to practice what has been observed. Where real models and components exist, students, after watching the video and trying the simulations, could transfer the learned behaviour to practice on the models and components.

They further expressed that to make the programme friendly to all learning perspectives, interactive multimedia could be employed; linking different learning materials and making them available to the learner such that the learner could learn a variety of procedures and adopt or construct his/her own method for efficiency.

Acquisition of psychomotor skills could also be achieved through the use of interactive multimedia (tutorials, video and sound technologies and simulations) as implemented in CAI, from imitation level through to higher naturalization level.

From the foregoing, it is seen that students in the Automotive Engineering could be taught basic facts and concepts pertaining to their programme using drill and practice and tutorials as implemented in CAI. This will enable the learners to master simple knowledge and facts which they could transfer to solve more complex problems.

CAI and Learner Motivation

Studies in the realm of individual learning have frequently demonstrated that the most effective teaching processes are those that rely heavily on constructive practices to motivate individuals. Since motivation has been recognized as a crucial factor in the learning process, it is naturally logical to apply the knowledge we have about motivation to one of the more contemporary and most promising modes of education, instruction via computer, or Computer-Assisted-Instruction (CAI).

Before motivation in CAI can be discussed, one must first familiarize himself/herself with the definition of motivation as well as several theories on motivation. McClelland (1987) wrote that motivation is a broad and loosely defined field, and "covers everything from detailed investigations of the physiological mechanisms involved in animal drives to elaborate analyses of the unconscious motives behind abnormal or symptomatic acts in a person to factor analyses of the motives of people assign to themselves to explain their behaviour" (p.1). Ford (1992) defined the concept of motivation as the organized patterning of an individual's personal goals, emotions, and personal agency beliefs.

Ideally, a student should be intrinsically motivated, meaning that the task itself is motivating and the student feels satisfaction from participating in the activity. However, when students are not intrinsically motivated (indicating low levels of motivation toward the particular task), external reinforcers may help increase the student's interest and motivation; e.g., grades, money, etc. In the case of CAI, extrinsic motivators (external reinforcers) can be built into the instruction to reinforce learners when they answer correctly, demonstrate effort through persistence, etc. Reinforcement following a particular desired behaviour improves the likelihood that such behaviour will reoccur. A reinforcer is a type of extrinsic motivator that increases the frequency of the event it ensues.

Motivation has a dual role in CAI. First, the students' levels of motivation prior to using CAI, greatly influences the overall success of their experience. Second, CAI can be a motivator to encourage students who have low levels of intrinsic motivation for learning a particular subject. This section of the write up will discuss both roles of motivation in CAI.

Models of Motivation

One well-known motivation theory is Keller's ARCS model (1987). Keller's model suggests strategies for stimulating the motivation to learn. ARCS is an acronym for the four points in his model: Attention, Relevance, Confidence and Satisfaction. Attention involves the arousal of interest in learners, the stimulation of an attitude of inquiry and the maintenance of attention. Relevance refers to tying instruction to make it relevant to the students' personal interests or goals. Confidence refers to the students' expectations for success, and Satisfaction refers to the process or results of the learning experience. Keller (1999) has suggested applying his ARCS model to CAI as well as to traditional learning environments.

Another important factor in motivation and CAI is self-determination. Deci and Ryan (1985) address the importance of self-determination (or choice) in intrinsic motivation. More recent research suggests that choice is an important factor in CAI as well (Kinzie, Sullivan, & Berdel, 1992; Yang & Chin, 1996).

Learner Characteristics

Learner characteristics vary from one individual to another. No two individuals think or learn in the same way or at the same pace. In traditional classroom instruction, some students are able to keep up with instruction and excel academically, while other students struggle to keep pace with those 'high-achievers'. Still other students are unable to keep up, no matter how hard they try and may be labelled by themselves and their peers as low achievers. Sometimes it is not the fault of the student for being unable to keep up. Often it is the method of instruction or lack of enrichment activities that impede 'lower-achieving students' academic progress.

CAI and Individualized Instruction

Using one method to teach all courses is simply not effective. Schieman and Jones (1992) argued that because each student learns differently, it is unreasonable and unfair for distance education courses to be delivered in one way only. For instance, the lecture approach only serves less than half of the student population in any classroom (Butler, 1984; D'Allura, 1983; Farquharson, 1995). Opportunities for group work, dialogue with the instructor, and self-directed projects are ways to meet the needs of different learners (Johnson, 1995; Kemp & Seagraves, 1995).

When teaching with computer programme, a possible solution is to provide alternative learning strategies from which the student can choose. Literature has shown that some individuals involved in a computer-aided instructional session do not effectively manage their own learning (Ross, 1997; Small and Grabowski, 1992). Some students make decisions which can be destructive, while others may simply not be motivated to learn using the computer. Mills and Ragan (1994) believe that adaptive interfaces, which match content presented to students' level of functioning, provide them with individualized instruction and improve learning outcomes.

Carver, Howard and Lavelle (1996) created virtual on-line learning environments that could accommodate students with different learning styles. An electronic learning style questionnaire (The Felder's Learning Style Inventory) was administered and used to match students to interfaces which were thought to be preferred by the different learning style groups. Reactions to the system were positive. The authors wrote:

> Adaptive hypermedia based on student learning styles provides the ability to individually tailor the presentation of course material to each student. The underlying idea of adaptive hypermedia based on learning styles is quite simple: adapt the presentation of course material so that it is most conducive to each student learning the course material. To a certain extent, each student is taking a different course based on what

material is most effective. This tailoring allows for efficient and effective student learning in the shortest possible period of time (1996 Ed Media CD-ROM Article # 486).

According to Small and Grabowski (1992), systems that give the user control over the learning process are empowering for some, while being destructive for others. The researchers warn that too much user control for some learners can lead to navigation decisions, resulting in skipping pertinent content or leaving the on-line environment before all content has been thoroughly covered (Schroeder, 1994). Castelli, Colazzo and Molinari (1996) discovered that many users of hypermedia "get lost" in hyperspace. The notion of becoming disoriented due to incessant "jumping around" is consistent with findings from Hammond (1989). Hence, a simple, yet effective, way to adapt instruction to meet the needs of all learners is to limit or expand the number of hypertext links provided. For example, students who find that they become lost in course content may wish to have the number of possible links to internal or external sources limited.

Auditory learners may wish to have information presented primarily through sound files, while visual learners may prefer to have mostly text or video-based instruction. Some students may prefer multiple choices, whereas others may enjoy essay or short answer examinations. Regardless of the ways in which content or the interface is modified, course creators are encouraged to develop and perfect computer learning adaptive systems of delivery. Continued research in the area will uncover better ways to deliver content so that each learner can achieve success.

Assessing Learning Styles

According to Wood, Ford, Miller, Sobczyk, and Duffin (1996) merely knowing one's learning style can help at-risk computer users adapt better to the technology, provided that learners are given a number of intervention strategies which can be employed when encountering difficulty.

Fauley (1991) wrote that learning style can influence the way students view learning from the computer. Some learners can find computer-based instruction "dehumanizing...and cruel" (p. 34), as these learners require personal attention, interaction with others, and human intervention throughout the learning process. Other learners, who can work relatively well alone, enjoy the opportunities that learning from the computer provides (Fauley, 1991).

Gee (1990) investigated the effects of learning preferences on post-secondary students' success in a distance education course. Students identified as being independent thinkers were found to be more successful in the course than those who desired working with others throughout the learning process. The author recommended that a learning style inventory be given to help instructors meet the needs of the students, aid course designers in developing innovative instructional design methods, and assist advisors in helping students make informed decisions.

Preferences for Learning

Many learners prefer processing information primarily through sight, and they can become frustrated with teachers who mainly use the traditional auditory (lecture) type of instruction. Likewise, others have strong preferences for more auditory or tactile (hands-on) types of instruction. When used properly, Computer Assisted Instruction (CAI) can enhance the learning process for learners of all types, regardless of learning preferences.

CAI helps to increase motivation through the use of a wide variety of software programs, which can stimulate learners' natural curiosity with the use of video (graphics), audio, and interactive applications. By allowing learners to work at a more individualized level and pace as is inherent in CAI, learners experience less frustration at being 'held back' when ready to move ahead or, as in the case of a slower learner, frantically trying to keep up. CAI also can release teachers from the burden of instructional delivery and grading, thereby allowing them more one-on-one time with individuals who need their assistance.

In a group setting, CAI has proven to assist in the levels of interaction between students and their teachers. An example of this is in a study done by Beauvois (1994) in which a group of French foreign language students participated in a lab-networked 'E-Talk' forum (or class chat room). The students, while not required to speak only French within the forum, were increasingly motivated to use only French and to interact with each other through the use of this forum. It was found that student motivation and self-efficacy were significantly increased through this online dialogue with their peers and that much of the stress and anxiety previously experienced by the students were greatly reduced through participating in this dialogue/forum.

Conversely, in a different study done by Hayward (1994), it was determined that students were less likely to interact with each other during in class discussions in an environment where computers are present but not used as a part of the class. It was also determined that many students were intimidated by the presence of computers and thus were less likely to interact as a result of this discomfort.

Nastasi and Clements (1993) found that children's motivation and positive social interactions increased as a result of cooperative computer environments. Specifically, it was shown that students who worked in pairs within LOGO environments that facilitated students' development of their own projects, fostered effective motivation, exchange of information and conflict resolution. In addition, this study indicated that children preferred to work in pairs rather than as individuals. Similarly, Fink (1990) suggested that Cooperative Computer Assisted Instruction (C-CAI) may be an effective approach for motivating students with behaviour disorders. Somewhat related to this were the results of Keeler and Anson's (1995) study that indicated students' anxiety was reduced the most after they participated in C-CAI rather than individualized CAI.

Self-Efficacy

With regards to motivation and achievement, how a student feels about his/her ability to learn is directly related to what is referred to as self-efficacy. According to Bandura (1997), self-efficacy is an individual's perception and belief of his or her capability to organize and execute the courses of action required to produce given attainments. People's beliefs in the efficacy have a wide-variety of effects on what courses of action they choose to take, how much effort they choose to exert and how long they will persevere when confronted with obstacles.

Computer technology is changing the basic structure of education by providing an instant interface for self-directed learning. To individuals who have a low sense of self-efficacy, technology is intimidating. However, to those students who are efficacious in their abilities, the use of technology appears simple. Often it simply comes down to the previous amount of experience that an individual has with computers and whether or not those experiences were positive or negative. For example, one's experience with technology plays a significant role in the efficacy one has towards using it in subsequent applications.

Teacher efficacy has a direct impact on the efficacy of their students. Teacher attitudes and beliefs of their own abilities to use computers and technology for both personal and instructional purposes are instrumental in how students perceive their own abilities. The confidence level and ability of a teacher in the use of technology will determine to what degree technology will be integrated into the curriculum. A teacher who is more confident in his or her abilities will:

1. Be more likely to use technology in the classroom
2. Will convey a greater sense of efficacy and 'can do' to their students (Abu-Jaber & Qutami, 1998).

Teacher efficacy is also greatly influenced by the amount and availability of support received from co-workers and administrators.

Achievement Level

Hativa (1989) conducted a study to determine differences in attitudes according to students' aptitude, gender, grade and Socio-Economic Status level, found that the attitudes of very high achieving students differed from the general population in that they liked working in a CAI environment due primarily to the diversity of activities that were made available to them through the CAI program. In contrast, the attitudes of very low -achieving students varied from the general trend in that they enjoyed CAI work much less. No significant differences were determined between attitudes of high versus low-achieving students on the positive feedback provided by CAI. Similarly, Liu and Rutledge (1997) found that learning with computers increased at risk students' motivation. Specifically, the at risk students who worked in a learner as-designer environment that simulated a real world multimedia production house showed significant increases in scores of intrinsic goal, task value, and self efficacy from pre to post test.

Socio-Economic Status (SES)

According to studies done by Hativa (1989), and one by Attewell and Battle (1997), students from different SES backgrounds varied on their preference from CAI work. It may be surprising to some that those students from lower SES families appeared to enjoy CAI significantly more than other students. This phenomenon was attributed to the positive feedback they received and the novelty of typing versus hand-writing a paper. Students from higher SES families and who, very likely, have access to computers at home, are not as motivated by the use of computers so the 'novelty effect' that inspired the other students has no effect on them as it has long since worn off.

CAI and Student Achievement Scores

The use of Computer-Based Instruction (CBI) has been shown to increase students' achievement scores (Collins, 1984, 1987), improve students' attitudes towards learning, produce substantial savings in instructional time, permit students to decrease the time taken to complete their studies in comparison to students in courses taught by conventional methods (Collins, 1986; Collins and Fletcher, 1987), and reduce the chances of students withdrawing from courses or not writing the final exams (Collins, 1990; Collins and Earle, 1990). Class remediation has been shown to be interesting by the use of computer test data (Collins and Fletcher, 1985).

Research Works in Computer Assisted Instruction (CAI)

In the view of Steinberg (1991), CAI is a computer presented instruction that is individualized, interactive and guided. He opines that CAI is not a method of instruction. Many methods are implemented in it, including drills and practice, Tutorial, games and simulations.

Freedman (1991) sees CAI as applications specially designed to teach a variety of subject areas to children and adults, in which learners receive feedback from the computer, which controls the sequencing of the subject matter. Proponents of CAI have high expectations for the computer as an instrument for identifying and meeting individual needs. Many studies conclude that using CAI to supplement traditional instruction is better that the instruction programme itself.

Harrison (1993) found that students who received computer instruction showed greater increases in their achievement scores in multiplication and subtraction than students who received traditional mathematical instruction.

Generally, students learn very well with science simulation software. Linn (1986) conducted an experiment in which eight eighth grade science classes used computers as lab partners for a semester. These students learn to use the computer to collect and display data, save and print out their reports. They used tools such as thermometer and light probes, which were attached to the computer, and the result were displayed on their computer screens. Linn found that the students instructed in the micro-based lab outperformed seventeen years old who took a standardized test on scientific knowledge. In addition, these computer-thought students demonstrated a very positive attitude toward experimentation.

Moore, Smith and Auner (1980) found higher student achievement with computer simulations when students had to interpret the result of the experiment to make decisions. If the student only had to follow directions and calculate the results, there was no difference between the experimental and the control groups.

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CAI research has generally been positive regarding the time it takes to learn concepts. Dence (1980) described several studies in which students learn more quickly with CAI than with the traditional instruction. Gleason (1981) reviewed CAI research and interviewed researchers. His conclusion regarding CAI was that it results in a 20 to 40 percent saving in time as compared with traditional methods of instruction.

Krein and Maholm (1990) found that Computer Assisted Instruction decreased by 25% the time it took students to learn the instructional material. A finding common in almost all studies is that the use of CAI reduces learning time, as compared with regular traditional classroom instruction.

Most instructors and teachers would want to find the best means of motivating their students to learn so as to improve their chances of success in the classroom. There are many studies that report students' positive attitudes toward the computer and how computers motivate students and help them maintain high interest (Hatfied, 1991).

An important factor in motivation and CAI is self-determination. Deci and Ryan (1985) address the importance of self-determination (or choice) in intrinsic motivation. More recent research suggests that choice is an important factor in CAI as well (Kinzie, Sullivan, & Berdel, 1992; Yang & Chin, 1996).

Summary

This section looked at what Computer Assisted Instruction (CAI) is. It was learnt that CAI as defined by The Association for Education Communication Technology (1977), is a method of instruction in which the computer is used to instruct the student and where the computer contains the instruction which is designed to teach, guide, and test the student until a desired level of proficiency is attained.

The history of CAI was also discussed in this section. Sidney Pressey and B.F. Skinner were mentioned as some of the pioneers who attempted to automate instruction as early as 1900 and 1954 respectively.

In addition, characteristics of CAI were discussed which included methods such as drill and practice, tutorials, videos, simulations and interactive multi-media, which are implemented in CAI. The researcher also reviewed related literature on CAI vis-à-vis learning theories and looked into how these could be applied in the teaching of Automotive Engineering Programmes.

The chapter concluded with findings of some research works conducted on Computer Assisted Instruction.

CHAPTER THREE

METHODOLOGY

This chapter looks at the method employed by the researcher in conducting this study. A description of the research design, population, sampling, data collection, research instrument and analysis of data is covered in this chapter.

This study was aimed at investigating the effect of Computer Assisted Instruction as a supplementary strategy on the academic achievement of technical students offering Automotive Engineering Programme. It was a quasi experimental study and the purpose was to see the relative effectiveness of independent variable, (teaching strategy) on the academic performance of students in Automotive Engineering.

In order to sustain the validity of the study, it was necessary to look into the various designs usually adopted in experimental research.

Research Design

Campbell and Stanley (1963) define internal validity as the basic requirements for an experiment to be interpretable while external validity addresses the question of generalizability.

They identified eight factors which affect internal validity including:

1. History, the specific events occurring between the first and second measurements in addition to the experimental variables.

2. Maturation, processes within the participants as a function of the passage of time (not specific to particular events), e.g., growing older, hungrier, more tired, and so on.
3. Testing, the effects of taking a test upon the scores of a second testing.
4. Instrumentation, changes in calibration of a measurement tool or changes in the observers or scorers may produce changes in the obtained measurements.
5. Statistical regression, operating where groups have been selected on the basis of their extreme scores.
6. Selection, biases resulting from differential selection of respondents for the comparison groups.
7. Experimental mortality or differential loss of respondents from the comparison groups.
8. Selection-maturation interaction, design contamination, etc.

If these factors are not controlled in the design, they may produce poor results which confound the effects of the independent variable.

Campbell and Stanley (1963) again described four factors jeopardizing external validity or representativeness:

1. Reactive or interaction effect of testing, the pretest sensitizes participants to aspects of the treatment and thus influences posttest scores.
2. Interaction effects of selection biases and the experimental variable.
3. Reactive effects of experimental arrangements, which would preclude generalization about the effect of the experimental variable upon persons being exposed to it in non-experimental settings.

4. Multiple-treatment interference, where effects of earlier treatments are not erasable.

With the above factors which affect the internal and external validity in mind, the researcher found the pre-test post-test quasi experimental design to be most appropriate for this study. In this design, subjects are not randomly assigned to experimental and controlled groups.

The following is a diagrammatic representation of the design:

X	=	O_1	T	O_2
C	=	O_1	-	O_2

Where	X	=	Experimental group
	C	=	Control group
	O_1	=	Pre-test
	T	=	Treatment given to the experimental group
	O_2	=	Post-test

According to Gribbons and Herman (1997), quasi-experimental designs are commonly employed in the evaluation of educational programs when random assignment is not possible or practical. The non-equivalent group, pretest-posttest design was employed for the study. This design is one of the most effective in minimizing threat due to reactive effects of experimental arrangements. In other words, utilizing quasi-experimental designs minimizes threats to external validity as natural environments do not suffer the same problems of artificiality as compared to a true experimental design. Since in quasi-experiments, the participants are left in their natural environments, findings in one may be applied to other subjects and settings, allowing for some generalizations to be made about the population.

Population

The purpose of the study was to investigate the relative effect of Computer Assisted Instruction as a supplementary strategy on the academic performance of technical students pursuing Automotive Engineering. Hence, technical school students following Automotive Engineering Programme in Ghana constituted the population for the study.

Sample and Sampling Procedure

Kumasi Technical Institute and Cape Coast Technical Institute were selected purposively for the study. These institutions were selected because both of them run Automotive Engineering Programmes. Again the administrators of these institutions accepted the request to involve their students in the study. The Automotive Engineering students in second year were selected for the study. This is because the learning package designed by the researcher was on second year lessons. To avoid interaction between the experimental and the control groups, these institutions, which are distanced from each other, were selected, thereby preventing contamination of the design. The students in Kumasi Technical Institute constituted the experimental group while the students in the Cape Coast Technical Institute constituted the control group. The pre-test which was conducted to test the equivalence of the two groups showed that Cape Coast Technical did slightly better than Kumasi Technical Institute. Kumasi Technical Institute was selected for the experimental group because the school had a good computer laboratory. Kumasi Technical Institute had 43 networked computers; well functioning in the computer laboratory but Cape Coast Technical had 13 computers of which only five were in good state. Twenty three (23) students in form 2A Automotive Engineering class, from Kumasi Technical Institute participated in the study and constituted the experimental group, while twenty four (24) form 2 students from Cape Coast Technical Institute were involved in the study and formed the control group. That is, intact classes were used for the study. Three participants from the experimental group were not available to take the post-test. Also, one participant from the control group travelled abroad, while three participants were dropped from the study because they were not regular to class during the period of the study. At the end of the study, the scores of forty students were used for analysis – twenty (20) participants from each group.

Research Instruments

The research instruments consisted of a pre-test and a post-test (see appendix B) taken by both the experimental and the control groups in order to obtain data. The purpose of the tests was to measure the achievement of students constituting the sample for the study. The post test items were based on the topics treated during the study period. These were:

1. Introduction to the motor vehicle chassis
2. The operation of the four-stroke cycle
3. The operation of the two-stroke cycle
4. The fuel system

5. Ignition system
6. Basic components of an engine

The pre-test items were based on some aspects of the topic "Introduction to motor vehicle chassis" which had been treated by both groups before the start of the study. The class masters and the course officers (Heads of Automotive Engineering Department) of both institutions reviewed the test items and approved of them. This was done to ensure that the test items were set at the appropriate levels of the sample and that the items had the desired content validity. The test items were made up of multiple-choice, dichotomous (True or False) and supply response questions. These types of test item were chosen to reduce the effect of subjectivity in scoring. The test items were scrutinised by experts in Automotive Engineering and ICT. They were pilot tested on behalf of the researcher by his colleagues in two other technical institutes in the country.

Data Collection Procedure

Before the treatment was applied, the pre-test test was administered to the sample by the researcher. To the experimental group, the teacher for the Automotive Engineering course (form 2A) was taken through a one day orientation to introduce her to the use of the CAI programme in teaching Automotive Engineering. She was also exposed to various web-sites to see simulations, tutorials, videos and animations on the topics to be taught during the period of the study. The topics selected for the study were among the topics to be studied for the term. In addition to the class teacher a research assistant was employed to assist with the data collection. The responsibility of the research assistant was to help the class teacher of the experimental group in guiding the group to explore the CAI and the web-sites which the students were to be exposed to.

After administering the pre-test, the two groups were both taught by their teachers as they normally do. The experimental group received supplementary teaching through the use of the learning package. During this period the experimental group received the treatment of independent variable, (CAI), through drill and practice and tutorials. These learning strategies were burnt onto compact discs (CD) and distributed to students constituting the experimental group. Constituents of the experimental group were further exposed to the following web-sites where they interacted with tutorials, animations, videos and simulations on the topics being treated in the normal classroom:

http://auto.howstuffworks.com/engine1.htm

http://auto.howstuffworks.com/engine2.htm

http://auto.howstuffworks.com/engine3.htm

http://auto.howstuffworks.com/engine4.htm

http://auto.howstuffworks.com/fuel-injection3.htm

http://www.youtube.com/watch?v=-G5TcWg0TMc&NR=1&feature=fvwp

http://www.youtube.com/watch?v=6BaECAbapRg&feature=related

http://www.youtube.com/watch?v=LuCUmQ9FxMU&feature=channel

http://www.youtube.com/watch?v=P-WYdrRKQvs&NR=1

http://www.youtube.com/watch?v=vzYGcDZXgWQ&feature=channel

http://www.youtube.com/watch?v=ydlRegFEaIk

http://www.youtube.com/watch?v=6BaECAbapRg&feature=related

http://www.google.com.gh/search?hl=en&q=YouTube+-

+CAD+Internal+Combustion+Engine&aq=f&oq

http://auto.howstuffworks.com/ignition-system.htm

The experimental group read tutorials on the operations of the various types of internal combustion engines and other components of the motor vehicle from the above web-sites. They again viewed simulations and videos of operation of the internal combustion engine, ignition system, fuel system and the motor vehicle as whole.

The participants in the control group were also kept busy in the workshop practicing with models and live components under the guidance of the workshop instructor and the researcher. This was done to control the variable of time and for the realization of the objective of the study. They were also given handouts (see appendix C) which contained copies of tutorials from some of the above web-sites. This was done in an attempt to expose both groups to similar materials but with different media. The study lasted for six weeks. The administration of the post test followed immediately after the treatment was over. The test was aimed at measuring the achievement of the students constituting the sample of the study. Final data for analysis were collected from 40 students - 20 from the experimental group and 20 from the control group.

Data Analysis

The pre-test conducted before the study took off was scored and scores of both groups were documented. The post-test scores of both groups were also documented.

To see the treatment effect, the group means were computed to determine the group that obtained higher average achievement on the variable of the pre-test and post-test. In addition, the significance of difference between the mean scores of the groups was tested at 0.05 level by applying *t*-test based on the pre-test and the post-test.

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter discusses the analysis and interpretation of data obtained from the pre-test and the post-test. Pre-test scores were secured to determine the equivalence of the two groups. The significance of the difference between the mean scores of the experimental and control groups on pre-test and post-test scores was found by applying the *t*-test of independence.

The Pre-Test

The pre-test was organized to test the equivalence of the two groups. In all there were ten test items which were based on the previous term's work. Each test item carried a maximum of one (1) mark. Hence the maximum and minimum attainable scores were 10 and 0 respectively.

Analysis of Pre-Test Scores for the Experimental Group

The pre-test scores were analysed to add meaning to the scores. In so doing a distribution table was drawn to show the various scores obtained, their frequencies, percentages and cumulative percentages.

Table 1, is a distribution table showing the pre-test scores for the experimental group.

Table 1

Score	Frequency	Percentage (%)	Cumulative Percentage (%)
4	1	5.0	5.0
5	11	55.0	60.0
6	2	10.0	70.0
7	6	30.0	100.0
Total	20	100.0	100.0

Distribution of Pre-Test Scores for Experimental Group

Summary Statistics for Pre-Test Scores for the Experimental Group

In order to ensure that the scores of the experimental group on pre-test are made more meaningful, the following statistics were applied to the scores. The mean, median, mode, standard deviation, variance and range of the scores were found. These statistics are presented in the table 2.

Table 2

Summary of Pre-Test Scores for the Experimental Group

Statistic	Value
Mean	5.65
Median	5.00
Mode	5.00
Std. Deviation	0.98809
Range	3.00

From Table 2, it is seen that the mean score for the experimental group on pre-test was 5.65 with a modal score of 5.00. However, the median indicates a score of 5.00; this suggests that a greater number of the students in the experimental group scored below the mean since the mean score was 5.65. Table 1 also indicates that 60% of the group scored below the mean while 40% performed above the mean. The range of the scores was found as 3.00; hence the group seems to be somewhat homogenous.

The group's performance on pre-test was also given a pictorial representation as shown in Figure 1.

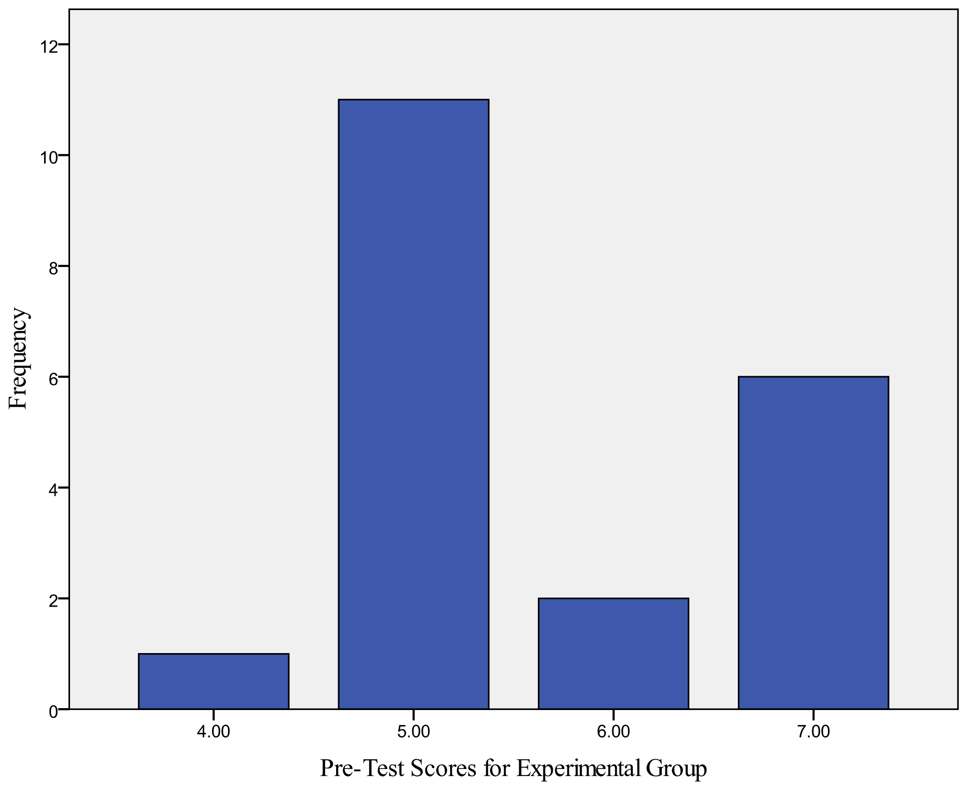

Fig 1: Distribution of pre-test scores for the experimental group

Table 1 and Figure 1 show that while only 1 student scored 4 out of the 10 test items, as many as 11 scored 5, with 2 and 6 of the students scoring 6 and 7 respectively.

Analysis of Pre-Test Scores for the Control Group

The pre-test scores of the control group were also analysed just like that of the experimental group. The scores, frequencies, percentages and cumulative percentages were tabulated as shown in Table 3.

Table 3

Distribution of Pre-Test Scores for Control Group

Score	Frequency	Percentage (%)	Cumulative Percentage (%)
4	1	5.00	5.00
5	8	40.00	45.00
6	9	45.00	90.00
7	1	5.00	95.00
9	1	5.00	100.00
Total	20	100.00	100.00

Table 3 indicates that the least score in this group (control) was 4 while the highest score was 9. The table also shows that 45% of the students in the control group scored 6 out of the 10 items.

Summary Statistics for Pre-Test Scores for the Control Group

To make the scores of the control group on pre-test more meaningful, the following statistics were applied to the scores. The mean, median, mode, standard deviation, variance and range of the scores were found. These statistics are presented in Table 4.

Table 4

Summary of Pre-Test Scores for the Control Group

Statistic	Value
Mean	5.70
Median	6.00
Mode	6.00
Std. Deviation	1.0311
Variance	1.063
Range	5.00

From Table 4, it is seen that the mean score for the control group on pre-test was 5.70 with a modal score of 6.00. However, the median indicate a score of 6.00; this suggests that a greater number of the students in the control group scored above the mean score since the mean is 5.70. Table 3 also indicates that 45% of the group scored below the mean while 55% performed above the mean. The range of the scores was found as 5.00; hence the group seems to be less homogenous. From Table 3 it is seen that 8 students representing 40% and 9 students representing 45% scored 5 and 6 respectively; making the group homogenous. However, the range of 5.00 may suggest that the group is heterogeneous. This is because the range was affected by the extreme scores of 4 and 9.

The group's performance on pre-test was also given a pictorial representation as shown in Figure 2.

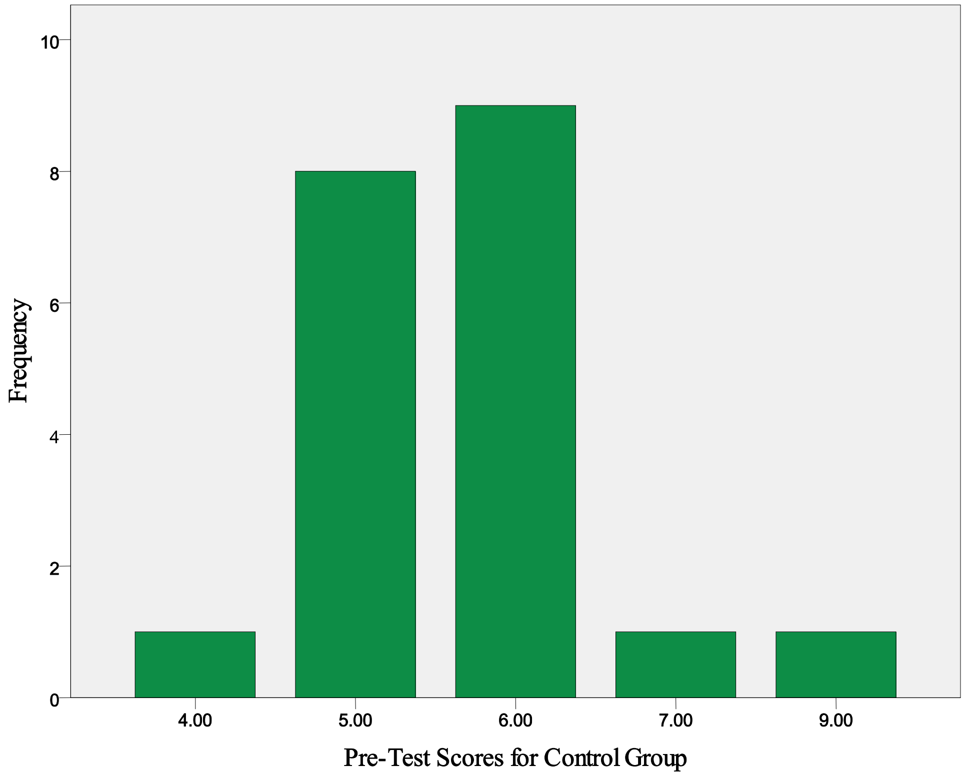

Fig 2: Distribution of pre-test scores for the control group

Figure 2 shows the distribution of pre-test scores for the control group. The extreme scores of 4 and 9, which affected the range, are depicted in the bar chart. That is, only one student scored 4; in the same manner only one student scored 9, which are the extreme scores which affected the range.

Comparative Analysis of Pre-Test for the Experimental and the Control Groups

The performances of the two groups were compared to find the relative achievement of the two groups. This was done by comparing the performances of the two groups using a bar chart. The significance of the difference between the mean scores of the experimental and control groups on pre-test scores was found out by applying the independent *t*-test. This was done to test the equivalence of the two groups.

Figure 3 is a bar chart showing the distribution of scores for the experimental and the control groups.

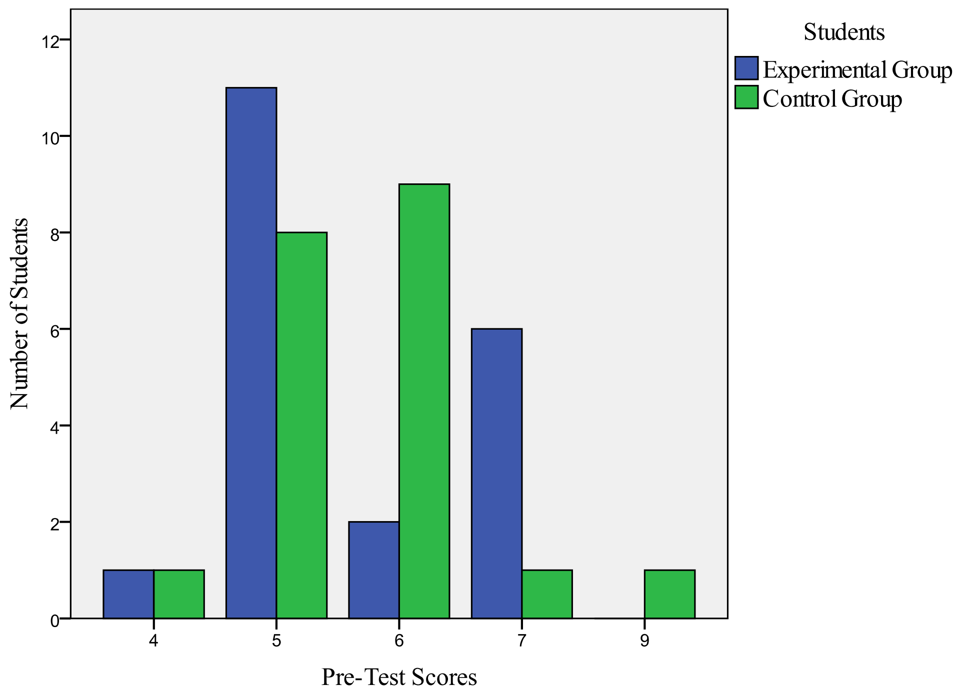

Fig 3: Distribution of score for control and experimental groups

The bar chart shows that one student from each group scored 4 which was the lowest score. On the other hand only one student from the control group scored 9, being the highest score in the pre-test for both groups. While as many as 9 students from the control group scored 6 only 2 students from the experimental group scored 6. On the face of it, the above figure appears to show that the control group did better than the experimental group in the pre-test. The difference between the groups was investigated using the *t*-test of independence.

Test of Significance

To test the significance of the difference between the two groups on the pre-test scores, the independent *t*-test was applied. The result of the *t*-test is as indicated in the Table 5.

Table 5

Difference Between the Scores of the Experimental and the Control Groups on the Pre-Test

Group	N	Mean	Std.Dev	Levene's Test for Equality of Variances	*t*-Test for Equality of Means		
				Sig.	t	Mean Difference	Sig.(2-tailed)
Experimental	20	5.65	0.98809	0.415	-0.157	-0.05	0.876
Control	20	5.70	1.0311				

In Table 5, it is shown that the mean scores of the experimental and the control groups were 5.65 and 5.70 respectively. This gives a mean difference of -0.05. The mean difference of -0.05 was subjected to the t-test to find out if it was significant. The independent t-test revealed that the t-value was -0.157 (Sig. 2-tailed = 0.876) and that the difference was not significant at the 0.05 significance level. This suggests that the two groups can be said to be equal in terms of their performances in the pre-test.

The standard deviations (variability) for the experimental as well as the control groups were 0.98809 and 1.03110 respectively. This suggests that the scores in the experimental group were closer to each other than those in the control group; an indication that the experimental group was more homogenous than the control group on the pre-test scores.

The Post Test

The post test was conducted to enable the researcher measure the effect of the intervention. A teacher made test comprising 20 items was constructed by the researcher. This was scrutinized by the heads of departments and the subject masters to ascertain the appropriateness of the test items. The test items were found to be at the right level of the students and had the required content and construct validity. Each item carried a score of 1; hence the maximum and minimum obtainable scores were 20 and 0 respectively.

Table 6

Distribution of Post-Test Scores for Experimental Group

Score	Frequency	Percentage (%)	Cumulative Percentage (%)
15	2	10.00	10.00
16	2	10.00	20.00
17	6	30.00	50.00
18	6	30.00	80.00
19	2	10.00	90.00
20	2	10.00	100.00
Total	20	100.00	100.00

Analysis of Post-Test Scores for the Experimental Group

The scores of the experimental group for the post-test conducted to determine the treatment ffect of the intervention, was presented and analyzed as shown in Tables 6 and 7.

Table 7

Summary of Post-test for the Experimental Group

Statistic	Value
Mean	17.50
Median	17.50
Mode	17.00 and 18.00
Std. Deviation	1.39548
Variance	1.947
Range	5.00

Table 7 indicates that the mean and the median scores of the experimental group in the pre-test recorded same value of 17.50. There were multiple modal scores of 17.00 and 18.00. From Table 6, it seen that 6 students scored 17 and also 6 students scored 18. The standard deviation and variance of the group scores were 1.39548 and 1.947 respectively, while the range was 5.

Graphical Representation of Post-Test Scores for the Experimental Group

The group scores were also given pictorial representation as shown in Figure 4.

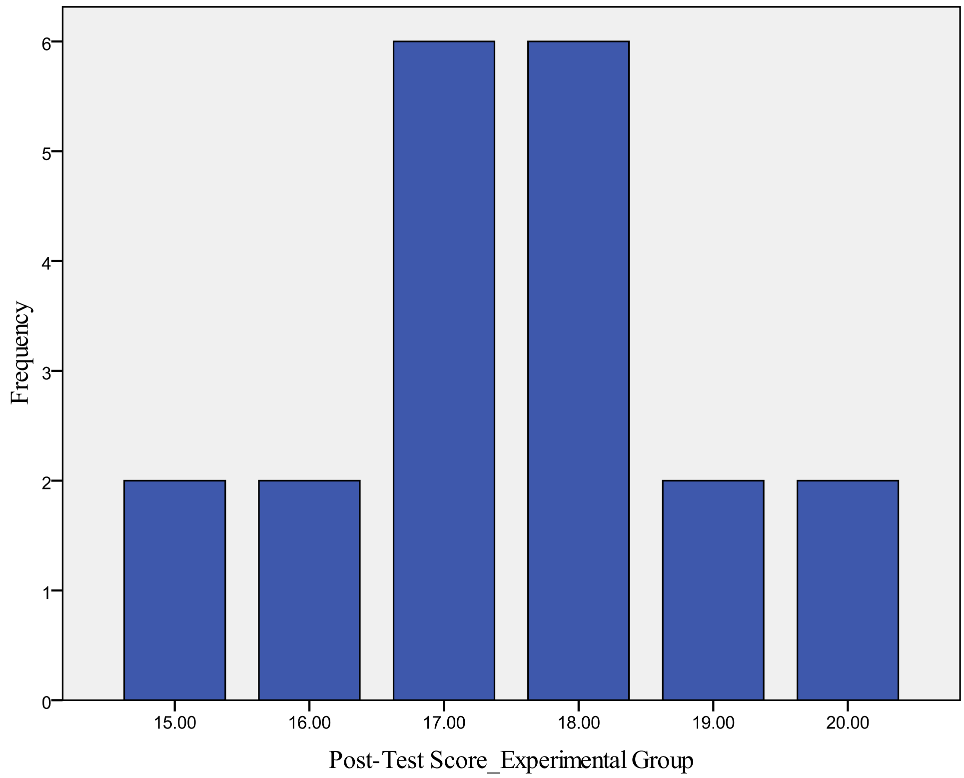

Fig 4: Distribution of post-test scores for the experimental group

In Figure 4 the modal scores of 17 and 18 are indicated by the two taller bars while the minimum and maximum scores of 15 and 20 are shown at the extreme ends, giving a range of (20-15) of 5.

Analysis of Post-Test Scores for the Control Group

The post-test scores for the control group were also analysed just like that of the experimental group. In Table 8 that follows, the scores, frequencies, percentages and cumulative percentages of the group are shown.

Table 8

Distribution of Post-Test Scores for Control Group

Score	Frequency	Percentage (%)	Cumulative Percentage (%)
12	4	20.00	20.00
13	6	30.00	50.00
14	3	15.00	65.00
15	2	10.00	75.00
16	2	10.00	85.00
18	1	5.00	90.00
19	1	5.00	95.00
20	1	5.00	100.00
Total	20	100.00	100.00

Table 8 shows maximum and minimum scores of 20 and 12 respectively. The summary statistics of the control group for the post-test is shown in Table 9.

Table 9

Summary of Post-test for the Control Group

Statistic	Value
Mean	14.35
Median	13.50
Mode	13.00
Std. Deviation	2.3681
Variance	5.947
Range	8.00

Table 9 shows the group median score as 13.50 with a mean score of 14.35. Table 8 also indicates that 50% of the students in the group, according to the cumulative percentages, scored 13 and below. Again, Table 8 shows that 65% of the group scored 14 and below; with a group mean of 14.35, suggesting that 65% of the group scored below the mean. The mode was 13 and the median 13.50, however the mean was 14.35; since the median and the mode are both lower the mean, it is an indication that majority of the group members performed below the mean. Table 9 indicates that standard deviation; variance and range of the group were 2.36810, 5.947 and 8.00 respectively.

Graphical Representation of Post-Test Scores for the Control Group

The Scores and the frequencies of the group were given pictorial representation to make it more meaningful and understandable. The pictorial representation is as shown in Figure 5.

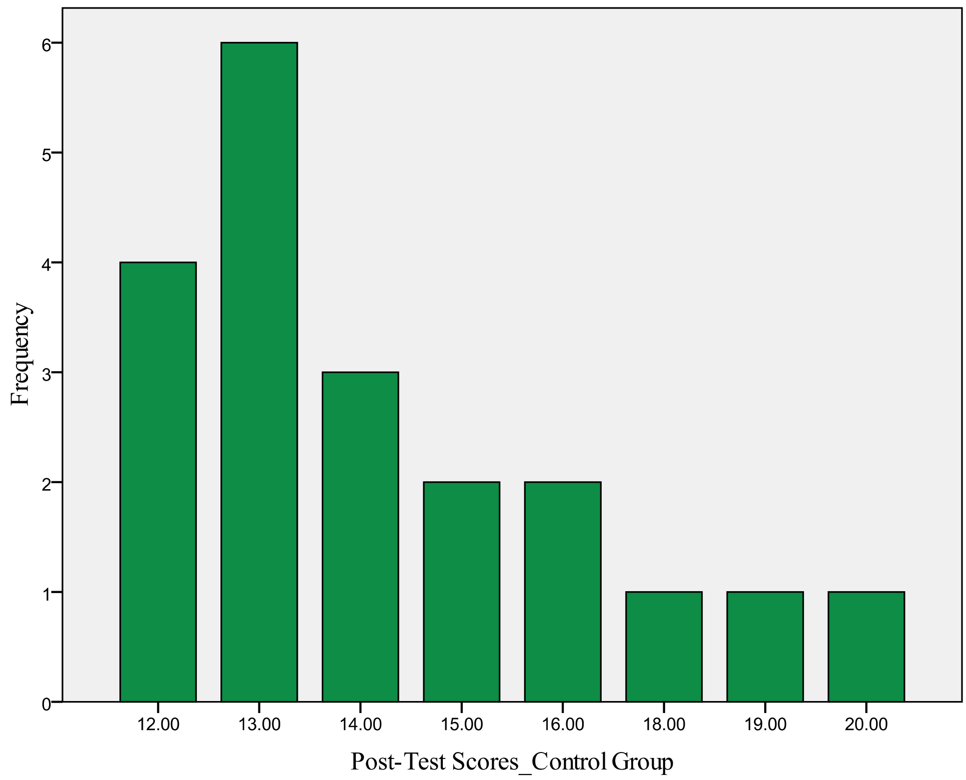

Fig 5: Distribution of post-test scores for the control group

In Figure 5, it shown that only one student scored 20, which was the maximum score and the highest score in the group, while 4 students scored 12, representing the lowest score for the group. Six students scored 13 representing the modal score for the group and indicated by the tallest bar in Figure 5. Table 6 as well as Figure 5 shows the range of scores for the control group as (20-12) 8; portraying a wide spread of the scores.

Comparative Analysis of Post-Test for the Experimental and the Control Groups

The researcher compared the post-test scores of the two groups in order to assess their performances. In doing this the researcher compared the means, median, standard deviations, the ranges and the modes of the two groups. These statistics are indicated in Table 10.

Table 10

Statistics for Experimental and Control Group Score

Students	Mean	Median	Std. Dev.	Range	Mode
Experimental	17.50	17.50	1.39548	5	17 .00 and 18.00
Control	14.35	13.50	2.3681	8	13.00

From Table 10 it is seen that while the experimental group had a mean of 17.50 the control had a means score of 14.35. Again the median for the experimental group is indicated as 17.50 while that of the control group is 13.50. Furthermore, the standard deviations and ranges were 1.39548 and 5 and 2.36810 and 8 for the experimental and the control groups respectively.

The summary statistics in Table 10 shows that the experimental group had a higher mean score (17.50) than the control group (14.35). This gives a difference of mean of 3.15 in favour of the experimental group. The standard deviations and ranges of the two groups as shown in Table 10 also indicates that the scores in the control group were spread wider than that of the experimental group; this suggests that the experimental group was again more homogeneous than the control group.

The scores and the frequencies of the post-test for the two groups were also given graphical representation, as shown in Figure 6, to make them more meaningful and understandable.

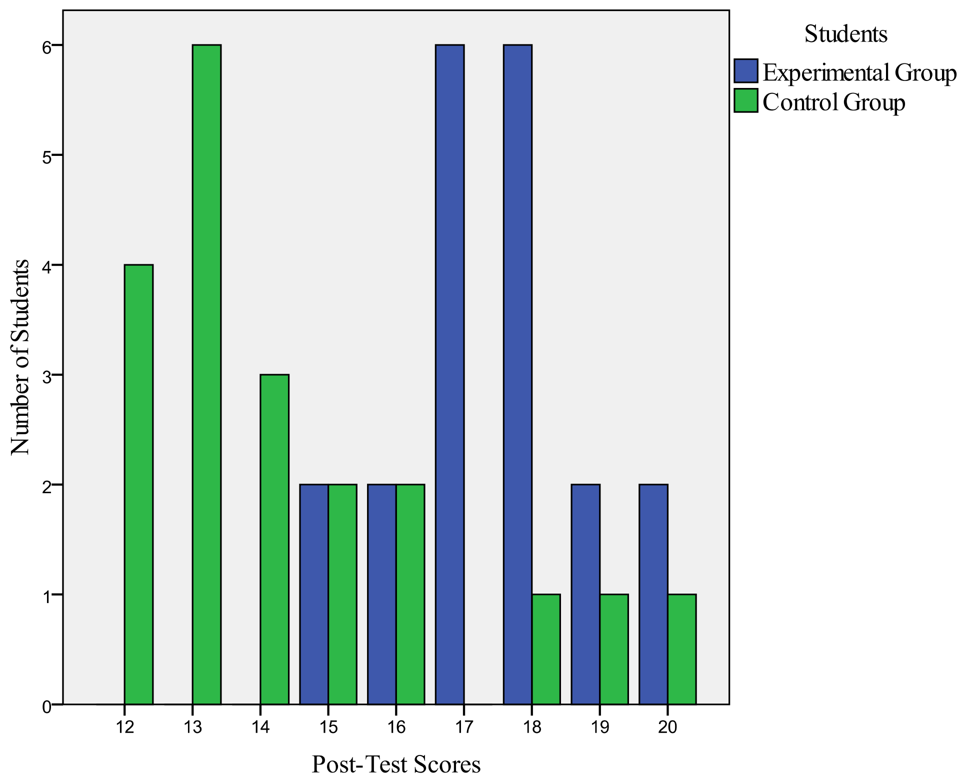

Fig 6: Distribution of post-test scores for control and experimental groups

Figure 6 shows that more of the students in the control group scored below 15. Again their scores were spread between 12 and 20, thus giving a range of 8. On the other hand the scores of the students of the experimental group were all above 14. Furthermore, their score were not as wide spread as those in the control group.

The researcher also compared the performances of each group against the normal curve using a Histogram as shown in Figure 7.

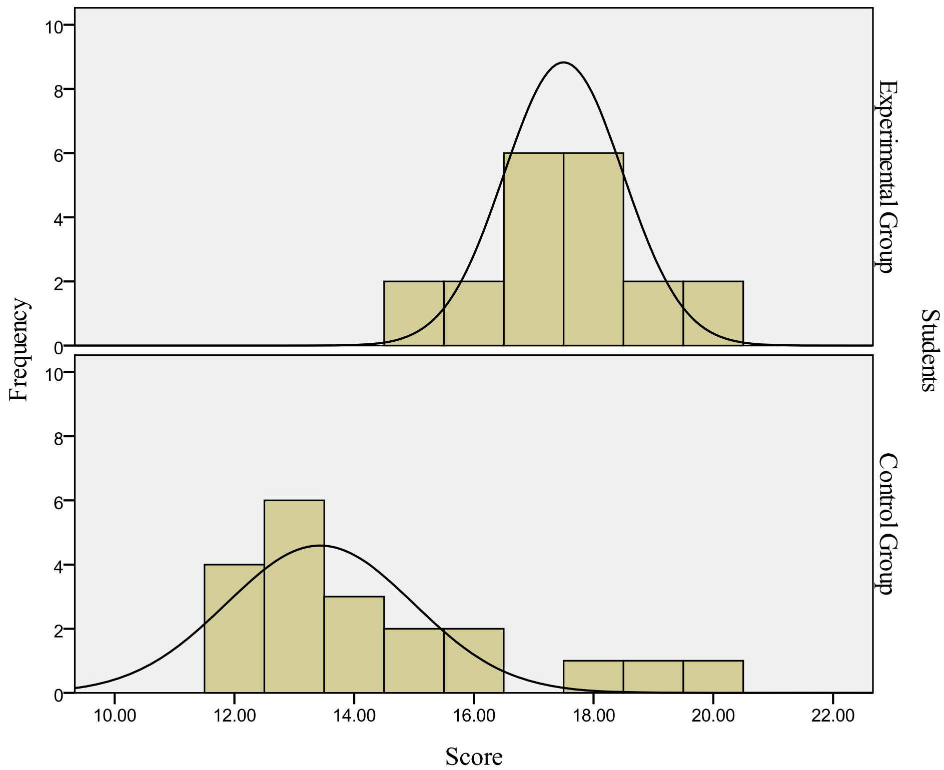

Fig 7: Normal curves showing post-test scores distribution for both groups

From Figure 7, it could be noted that the performance of the experimental group appears to be better than that of the control group. The shift of the distribution of the scores of the experimental group provides evidence for this observation.

Test of significance

The research question that guided the study was “is there a significant difference in the achievements of Automotive Engineering students when they are taught using the traditional classroom method and when they are taught using CAI?” The following null and alternatives hypotheses were derived from the research question.

H_0: There is no significant difference between the achievements of students who learn Automotive Engineering through the traditional method and that of students who learn through computer program:

H_1: There is a significant difference between the achievements of students who learn Automotive Engineering through traditional method and that of students who learn through computer program:

To test the significance of the difference between the two groups on the post-test scores, the independent *t*-test was applied. The result of the *t*-test is as indicated in the Table 11.

Table 11
Difference Between the Scores of the Experimental and the Control Groups on the Post-Test

Group	N	Mean	Std.Dev	Levene's Test for Equality of Variances		*t*-Test for Equality of Means		
				F	Sig.	t	Mean Difference	Sig.(2-tailed)
Experimental	20	17.50	1.395	4.287	0.045	5.125	3.15	0.000
Control	20	14.35	2.368					

In Table 11, it is shown that the mean scores of the experimental and the control groups were 17.50 and 14.35 respectively. This gives a mean difference of 3.15. The mean difference of 3.15 was subjected to the *t*-test to find out if it was significant. The independent *t*-test revealed that the *t*-value was 5.125 (Sig. 2-tailed = 0.000) and that the difference was statistically significant at the 0.05 significance level in favour of the experimental group. This implies that the experimental group performed better on the post –test than the control group although the pre-test showed that the groups were alike in terms of their performances before the intervention. This suggests that the intervention had an impact on the achievements of the students in the experimental group. The discussions on the above findings are given in the section that follows.

Discussion

Many related studies conducted comparing students using the traditional classroom method and those using CAI supplement almost invariably concluded that those students using CAI supplement out-performed those using the traditional classroom method.

In a similar study, Harrison (1993) also found that students who received CAI showed greater increases in their achievement scores. The improved performance of the students in the experimental group could be attributed to the improved attitudes towards learning that they exhibited during the study period. Students in this group were stimulated by the simulations of engine components. These stimulations resulted in greater motivation to learn, not only in the computer laboratory, but also at the internet cafes.

CAI helps to increase motivation through the use of a wide variety of software programs, which can stimulate learners' natural curiosity with the use of video (graphics), audio, and interactive applications. By allowing learners to work at a more individualized level and pace as is inherent in CAI, learners experience less frustration at being 'held back' when ready to move ahead or, as in the case of a slower learner, frantically trying to keep up. CAI also can release teachers from the burden of instructional delivery and grading, thereby allowing them more one-on-one time with individuals who need their assistance.

Using one method to teach all courses is simply not effective. Schieman and Jones (1992) argued that because each student learns differently, it is unreasonable and unfair for distance education courses to be delivered in one way only. For instance, the lecture approach only serves less than half of the student population in any classroom (Butler, 1984; D'Allura, 1983; Farquharson, 1995). Opportunities for group work, dialogue with the instructor, and self-directed projects are ways to meet the needs of different learners (Johnson, 1995; Kemp & Seagraves, 1995).

When teaching with computer program, a possible solution is to provide alternative learning strategies from which the student can choose. Literature has shown that some individuals involved in a computer-aided instructional session do not effectively manage their own learning (Ross, 1997; Small and Grabowski, 1992). Some students make decisions which can be destructive, while others may simply not be motivated to learn using the computer. Mills and Ragan (1994) believe that adaptive interfaces, which match content presented to students' level of functioning, provide them with individualized instruction and improve learning outcomes. In this study, students of the experimental group were provided with a variety of computer learning programs – tutorials, drill and practice, simulations and videos – enabling them to choose from these varieties those methods that help them to learn best. The improved performances of the constituents of this group could be attributed to the presence of variety of methods from which they were able to choose the ones that best meet their learning preferences.

In another study, Carver, Howard and Lavelle (1996) created virtual on-line learning environments that could accommodate students with different learning styles. An electronic learning style questionnaire (The Felder's Learning Style Inventory) was administered and used to match students to interfaces which were thought to be preferred by the different learning style groups. Reactions to the system were positive. The authors observed that adaptive hypermedia based on student learning styles provides the ability to individually tailor the presentation of course material to each student. The underlying idea of adaptive hypermedia based on learning styles is quite simple: adapt the presentation of course material so that it is most conducive to each student learning the course material. To a certain extent, each student is taking a different course based on what material is most effective. This tailoring allows for efficient and effective student learning in the shortest possible period of time (1996 Ed Media CD-ROM Article # 486).

In similar studies, the use of computer-based instruction (CBI) has been shown to increase students' achievement scores (Collins, 1984, 1987), improve students' attitudes towards learning, produce substantial savings in instructional time, permit students to decrease the time taken to complete their studies in comparison to students in courses taught by conventional methods (Collins, 1986; Collins & Fletcher, 1987), and reduce the chances of students withdrawing from courses or not writing the final exams (Collins, 1990; Collins and Earle, 1990). Class remediation has been shown to be interesting by the use of computer test data (Collins and Fletcher, 1985).

Most instructors and teachers would want to find the best means of motivating their students to learn so as to improve their chances of success in classroom. There are many studies that report students' positive attitudes toward the computer and how computers motivate students and help them maintain high interest (Hatfied, 1991).

In the present study, students of the experimental group completed the course contents (topics being treated) 12 days ahead of the scheduled 42 days making the study period, while the control group were able to just complete the topics on time. This agrees with (Collins, 1986; Collins & Fletcher, 1987), that students taught with CAI supplement produce substantial savings in instructional time, permit students to decrease the time taken to complete their studies in comparison to students in courses taught by conventional methods.

CAI research has generally been positive regarding the time it takes to learn concepts. Dence (1980) described several studies in which students learn more quickly with CAI than with the traditional instruction. Gleason (1981) reviewed CAI research and interviewed researchers. His conclusion regarding CAI was that it results in a 20 to 40 percent saving in time as compared with traditional methods of instruction.

Krein and Maholm (1990) also found that Computer Assisted Instruction decreased by 25% the time it took students to learn the instructional material. A finding common in almost all studies is that the use of CAI reduces learning time, as compared with regular traditional classroom instruction.

More often than not, students learn very well with science simulation software. Linn (1986) conducted an experiment in which eight eighth grade science classes used computers as lab partners for a semester. These students learnt to use the computer to collect and display data, save and print out their reports. They used tools such as thermometer and light probes, which were attached to the computer, and the result were displayed on their computer screens. Linn found that the students instructed in the micro-based lab out-performed seventeen years old who took a standardized test on scientific knowledge. In addition, these computer-thought students demonstrated a very positive attitude toward experimentation. Much like Linn's study, the students in the experimental group for this study had time to study with computer programs, interacting with drills and practice, tutorials and simulations to foster their understanding of basic facts, concepts and principles involved in the study of Automotive Engineering. In this study the simulations of vehicle components used by the experimental group enabled them to learn well and focused on the subject matter. This might have contributed to their improved performance in the post-test result.

Moore, Smith and Auner (1980) also found higher student achievement with computer simulations when students had to interpret the result of the experiment to make decisions. If the student only had to follow directions and calculate the results, there was no difference between the experimental and the control groups.

Although group work may be difficult to achieve in CAI, the instructor may wish to give students the option to collaborate for certain assignments. Group work can be a highly motivating and effective learning tool, especially for those students who may be having trouble with learning from the computer and/or who are inherently social individuals (Ross, 1997). Ross recommended that, whenever possible, students who voice dissatisfaction with the computer should be allowed to work collaboratively on assignments. In this way, the focus shifts from learning from a machine, to learning with another human being while using a machine. In this study there were sub-groupings under both the experimental and the control groups. That is, each group was further divided into 5 groups; with the experimental students studying in groups, it was observed that those students with “techno-phobias” learnt how to learn using the computer from their peers and quickly overcame their anxiety and became used to the phenomenon. In this way all students in the experimental group had the opportunity to learn in groups and as individuals. This could be the cause of the closeness of the scores of the students of the experimental group resulting in more homogeneous group for the experimental group in the post-test result.

Proponents of CAI have high expectations for the computer as an instrument for identifying and meeting individual needs. Many studies conclude that using CAI to supplement traditional instruction is better than the instruction programme itself. The use of CAI has been shown to increase students' achievement scores (Collins, 1984, 1987), improve students' attitudes towards learning, produce substantial savings in instructional time, permit students to decrease the time taken to complete their studies in comparison to students in courses taught by conventional methods only.

To sum up, the results of the study indicate that CAI, as a supplementary strategy to support traditional teaching methods, improves learners’ performance in Automotive Engineering Programme. It should however be stated that there is no one best delivery style for all subject areas. The choice of delivery style, computer program or the lecture method and whatever style the instructor wish to use should be determined by the nature of the course content.

However if students are expected to learn and understand complex concepts and operation principles of mechanisms such as which occur in Automotive Engineering Programme, then computer programs such as tutorials, drills and simulations could be of immense help to the learners.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

This study was designed to investigate the effect of Computer Assisted Instruction as a supplementing strategy on the academic performance of technical students offering Automotive Engineering Programme.

The main objective of the study was to find out the relative effect of Computer Assisted Instruction as supplementing strategy on the academic performance in Automotive Engineering.

To achieve the objective of the study, following the research question was addressed through testing the null (H_0): Is there a significant difference in students' achievements when they are taught using the traditional method or CAI supplement?

H_0: There is no significant difference between the mean scores of students taught Automotive Engineering with CAI as supplementing strategy and those taught without CAI.

H_1: There is significant difference between the mean scores of students taught Automotive Engineering with CAI as supplementing strategy and those taught without CAI.

Technical school students pursuing Automotive Engineering constituted the population for the study. The sample for the study included only second year automotive students. Second year Automotive Engineering students in the Kumasi Technical Institute constituted the experimental group while their counterpart in the Cape Coast Technical Institute formed the control group.

A pre-test was conducted to determine the equivalence of the groups. The study started with 24 participants in the control group and 23 participants in the experimental group. However 4 participants from the control group were dropped because; one travelled abroad and was not available to take the post-test, and the other three were not regular in class. Similarly, three participants from the experimental group were dropped for irregularity in class.

During the study both groups were taught by their class teachers as they normally do. The experimental group received supplementary teaching through CAI. During this period, the experimental group received the treatment of independent variable, (CAI), through drill and practice and tutorials. Constituents of the experimental group were, in addition, exposed to web-sites where they interacted with tutorials, animations, videos and simulations on the topics being treated in the normal classroom.

About the same time the control group was also kept busy in the workshop practicing with model and live components under the guidance of the workshop instructor and the researcher. This was done to control the variable of time and for the realization of the objective of the study. They were also given handouts which contained copies of tutorials from some of the web-sites. This was done in an attempt to expose both groups to similar materials but in different forms. The study lasted for six weeks. The administration of the post test followed immediately after the treatment was over. The test was aimed at measuring the achievement of the students constituting the sample of the study. Final data for analysis were collected from 40 students – 20 students from each group.

In order to obtain data for analysis, the scores of the pre-test and post-test were documented. Having obtained the scores, group means were computed to determine the group that obtained higher average achievement on the variable of the pre-test and post-test. In addition the significance of difference between the mean scores of the groups was tested at 0.05 level by applying *t*-test based on the pre-test and the post-test.

Analysis of data showed that the students taught through CAI as supplementary strategy performed significantly better.

Conclusions

Based on the statistical analysis and the findings of the study, the following conclusions were drawn:

1. The application of Computer Assisted Instruction as a supplementary strategy in teaching of Automotive Engineering was found to be more effective.
2. Throughout the study, it became evident that students forming the experimental group approached learning with much excitement than the control group.

Recommendations

Considering the findings and the conclusions drawn from the study, the following recommendations are made:

1. More computer resources should be made available to schools, most especially, schools and institutions that run practical oriented programmes so that students can learn and practise through simulations.
2. Automotive repair shops and companies should consider taking advantage of computer-based simulations in training their work force as this will not only save them time but money as well.
3. A true experimental study with samples selected from the same institution could be conducted to further examine the effectiveness of Computer Assisted Instruction as supplementary strategy.
4. Similar studies should be conducted in other subject areas, such as, electrical engineering, mechanical (production) and physics.
5. The study could be replicated with bigger samples from different institutions, representing a wider range of ability.

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APPENDICES

Appendix A

INTRODUCTION LETTER

CENTRE FOR CONTINUINGEDUCATION

Tel No: 042 - 36946
Fax: 042 - 36946
E-mail cceucc@yahoo.com

University Post Office
Cape Coast

(UNIVERSITY OF CAPE COAST)

Our Ref. No: CCE/143/Vol.1/11

24rd October, 2009

Your Ref. No:

TO WHOM IT MAY CONCERN

This is to certify that **Mr. Isaac Adar MacCarthy** with registration number **ED/MIT/07/0008** is pursuing a two year M.Ed degree in Information Technology at the University of Cape Coast.

He is conducting a research on the topic "The effects of teaching and learning with computers on academic performance of students".

We will strongly appreciate any courtesy extended to him.

Thank you.

Palmas Anyagre

(Programme Facilitator)

Appendix B

Pre-test

Name of School:

Name of Student:

Please, you are required to answer all the questions. Each question carries a maximum of one (1) mark.

Time: 30minutes

1. What is the name given to the skeleton of a car?
   a) Chassis
   b) Axle
   c) Engine
   d) Gear box
2. To disengage and engage the drive from the engine to the rest of the transmission system, the ……. is used.
   a) Propeller shaft
   b) Gear box
   c) Rear axle
   d) Clutch
3. Which of the following is used for torque multiplication in the motor vehicle?
   a) Engine
   b) Gear box
   c) Propeller shaft
   d) Clutch
4. What is the name of the component shown below? ……………

5. Which of the following component provides the power source for the motor car?
   a) Engine
   b) Sun wheels
   c) Propeller shaft
   d) Half shaft
6. Which component enables the outer wheel to rotate faster than the inner wheel when negotiating a curve?
   a) Final drive
   b) Half shaft
   c) Wheel hub
   d) Tyres

7. Which of the following systems converts the mechanical energy possessed by the vehicle to heat energy?
   a) Transmission system
   b) Steering system
   c) Suspension system
   d) Braking system
8. Which of the following is NOT a component of the transmission system?
   a) Steering wheel
   b) Gear box
   c) Clutch
   d) Propeller shaft
9. In the transmission system, the gear box is fitted directly to the flywheel, followed by the clutch and the propeller shaft.
   a) True
   b) False
10. Name the component shown below. …………………

Appendix B

Post-Test

Name of student: Name of School:

Please, you are required to answer all the questions. Each question carries a Maximum of one (1) mark. Duration: 1 Hour (60 minutes)

1. In a four stoke four cylinder engine power stroke occurs at every ……turn of the crankshaft.
   a) 360°
   b) 180°
   c) 90°
   d) 120°
2. In a single point petrol injection system, the injector ignites the fuel.
   a) True
   b) False
3. Which component transfers the thrust from the piston to the crankshaft
   a) Piston rings
   b) Connecting rod
   c) Camshaft
   d) Crank web
4. Which of the following ensures efficient distribution of fuel?
   a) Side drop carburetor
   b) Single point injection
   c) Multi point injection
   d) Down drop injection
5. The space left above the piston when the piston is at TDC is called….
   a) Clearance volume
   b) Swept volume
   c) Stroke
   d) Throw
6. The length between the centre line of the crankpin and the centre line of the main bearing of the crankshaft is called…….
   a) Crank web
   b) Throw
   c) Stroke
7. The purpose of the oil scraper ring is to ……
   a) Provide gas tight seal in the cylinder
   b) Lubricate the connecting rod
   c) Prevent excess oil from entering the combustion chamber
   d) Ignite the fuel in the combustion chamber

8. Which of the following components converts the reciprocating motion of the piston to rotary motion?
    a) Gudgeon pin
    b) Connecting rod
    c) Camshaft
    d) Piston rings
9. Which of the following is **NOT** a component of the petrol fuel supply system
    a) Carburetor
    b) Spark plug
    c) Fuel pump
    d) Petrol tank
10. With reference to petrol engine, the compressed air-fuel mixture is ignited by the:
    a) Injector
    b) Exhaust valve
    c) Spark plug
    d) Combustion chamber
11. Flexible hose are used in the fuel supply system to
    a) Cause engine vibration
    b) Withstand engine vibration
    c) Allow engine to run fast
    d) Cause free flow of fuel
12. Air-fuel mixture suitable for cold starting is ?
    a) 8:1
    b) 10:1
    c) 12:1
    d) 3:1
13. In a two-stroke petrol engine the intake of air-fuel mixture into the crankcase is controlled by…
    a) Mushroom valve
    b) Reed valve
    c) Rocker valve
    d) Sling valve
14. The process of expelling exhaust gases from the cylinder and charging it with fresh mixture is known as……..
15. The purpose of the ignition coil is to….
    a) Increase the current from the battery
    b) Produce a spark in the cylinder
    c) Increase the voltage from the battery
    d) Distribute high current to the ignition cables
16. The ratio of the camshaft speed to the speed of the crankshaft in a four stroke engine is…
    a) 1:1
    b) 1:2
    c) 2:1
    d) 4:1

17. What is the purpose of the deflector on the crown of the piston of the two stroke petrol engine
    a) Direct exhaust gases to the exhaust pipe
    b) Prevent fresh mixture from leaving the crankcase
    c) Direct fresh mixture to the top of the cylinder
    d) Provide gas-tight seal in the cylinder
18. In a four stroke engine the flywheel is used to….
    a) Increase the wait of the engine
    b) Help the engine to start fast
    c) Keep the engine running through the idling strokes
    d) Increase the number of idling strokes so that the engine can run fast
19. Which of the following drives the valves
    a) Drive shaft
    b) Half shaft
    c) Cam shaft
    d) Plain shaft
20. Which of the following is used to control the inflow and outflow of gases into the cylinder in the two-stroke petrol engine?
    a) Valve stem
    b) Cams
    c) Ports
    d) Tappet

Appendix B

Test Scores for Experimental Group

Pre-Test	Post-Test
7	18
6	19
5	19
7	18
5	16
5	17
5	18
5	17
7	17
7	20
5	15
5	18
5	17
6	18
7	18
7	20
5	17
5	16
4	17
5	15

Test Scores for Control Group

Pre-Test	Post-Test
6	16
6	19
6	13
6	14
4	13
5	12
6	13
6	18
7	16
6	13
6	14
5	12
5	13
5	15
5	14
5	15
5	12
6	13
9	20
5	12

Appendix C

Supplementary Learning Materials for Control Group

Internal Combustion

The principle behind any reciprocating internal combustion engine: If you put a tiny amount of high-energy fuel (like gasoline) in a small, enclosed space and ignite it, an incredible amount of energy is released in the form of expanding gas. You can use that energy to propel a potato 500 feet. In this case, the energy is translated into potato motion. You can also use it for more interesting purposes. For example, if you can create a cycle that allows you to set off explosions like this hundreds of times per minute, and if you can harness that energy in a useful way, what you have is the core of a car engine!

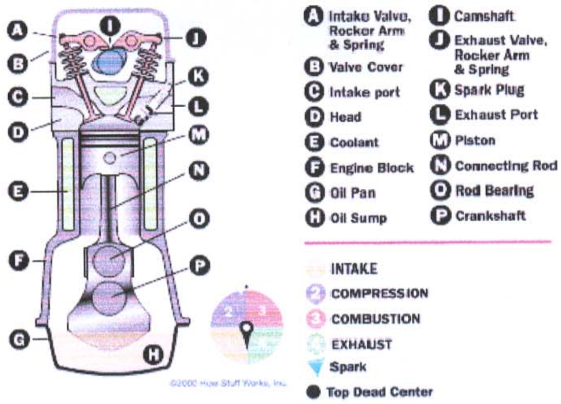


Figure 1

Almost all cars currently use what is called a **four-stroke combustion cycle** to convert gasoline into motion. The four-stroke approach is also known as the **Otto cycle**, in honor of Nikolaus Otto, who invented it in 1867. The four strokes are illustrated in **Figure 1**. They are:

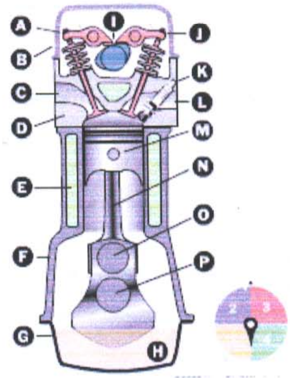
- Intake stroke
- Compression stroke
- Combustion stroke
- Exhaust stroke

You can see in the figure that a device called a **piston** replaces the potato in the potato cannon. The piston is connected to the **crankshaft** by a **connecting rod**. As the crankshaft revolves, it has the effect of "resetting the cannon." Here's what happens as the engine goes through its cycle:

1. The piston starts at the top, the intake valve opens, and the piston moves down to let the engine take in a cylinder-full of air and gasoline. This is the **intake stroke**. Only the tiniest drop of gasoline needs to be mixed into the air for this to work. (Part 1 of the figure)
2. Then the piston moves back up to compress this fuel/air mixture. **Compression** makes the explosion more powerful. (Part 2 of the figure)
3. When the piston reaches the top of its stroke, the spark plug emits a spark to ignite the gasoline. The gasoline charge in the cylinder **explodes**, driving the piston down. (Part 3 of the figure)
4. Once the piston hits the bottom of its stroke, the exhaust valve opens and the **exhaust** leaves the cylinder to go out the tailpipe. (Part 4 of the figure)

Now the engine is ready for the next cycle, so it intakes another charge of air and gas.

Notice that the motion that comes out of an internal combustion engine is **rotational**, while the motion produced by a potato cannon is **linear** (straight line). In an engine the linear motion of the pistons is converted into rotational



Appendix C

Supplementary Learning Materials for Control Group

Engine Valve Train and Ignition Systems

Most engine subsystems can be implemented using different technologies, and better technologies can improve the performance of the engine. Let's look at all of the different subsystems used in modern engines, beginning with the valve train.

The valve train consists of the valves and a mechanism that opens and closes them. The opening and closing system is called a camshaft. The camshaft has lobes on it that move the valves up and down, as shown in **Figure 5**.

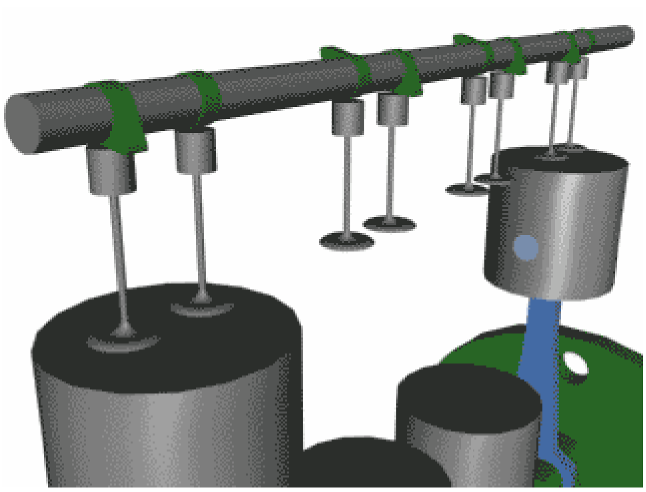


Figure 5. The camshaft

Most modern engines have what are called **overhead cams**. This means that the camshaft is located above the valves, as you see in Figure 5. The cams on the shaft activate the valves directly or through a very short linkage. Older engines used a camshaft located in the sump near the crankshaft. **Rods** linked the cam below to **valve lifters** above the valves. This approach has more moving parts and also causes more lag between the cam's activation of the valve and the valve's subsequent motion. A **timing belt** or timing chain links the crankshaft to the camshaft so that the valves are in sync with the pistons. The camshaft is geared to turn at one-half the rate of the crankshaft. Many high-performance engines have four valves per cylinder (two for intake, two for exhaust), and this arrangement requires two camshafts per bank of cylinders, hence the phrase "dual overhead cams."

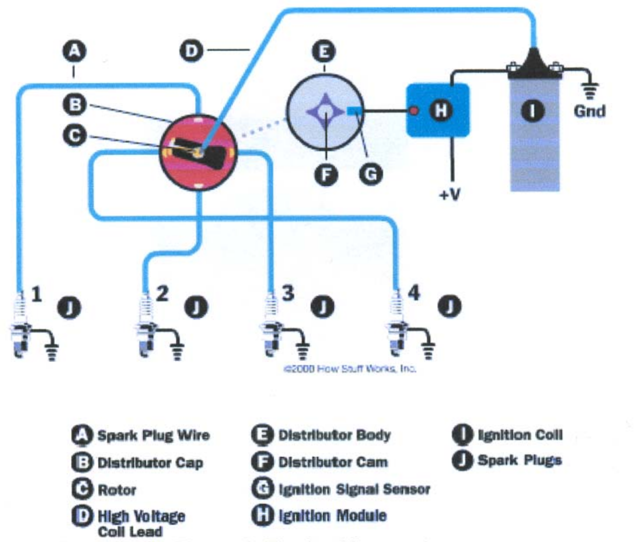


Figure 6. The ignition system

The **ignition system** (Figure 6) produces a high-voltage electrical charge and transmits it to the spark plugs via **ignition wires**. The charge first flows to a **distributor**, which you can easily find under the hood of most cars. The distributor has one wire going in the center and four, six, or eight wires (depending on the number of cylinders) coming out of it. These **ignition wires** send the charge to each spark plug. The engine is timed so that only one cylinder receives a spark from the distributor at a time. This approach provides maximum smoothness. http://auto.howstuffworks.com/engine4.htm

The Fuel System

In trying to keep up with emissions and fuel efficiency laws, the fuel system used in modern cars has changed a lot over the years. The 1990 Subaru Justy was the last car sold in the United States to have a carburetor; the following model year, the Justy had fuel injection. But fuel injection has been around since the 1950s, and electronic fuel injection was used widely on European cars starting around 1980. Now, all cars sold in the United States have fuel injection systems.

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In this article, we'll learn how the fuel gets into the cylinder of the engine, and what terms like "multi-port fuel injection" and "throttle body fuel injection" mean.

The Fall of the Carburetor

For most of the existence of the internal combustion engine, the carburetor has been the device that supplied fuel to the engine. On many other machines, such as lawnmowers and chainsaws, it

still is. But as the automobile evolved, the carburetor got more and more complicated trying to handle all of the operating requirements. For instance, to handle some of these tasks, carburetors had five different circuits:

- **Main circuit** - Provides just enough fuel for fuel-efficient cruising
- **Idle circuit** - Provides just enough fuel to keep the engine idling
- **Accelerator pump** - Provides an extra burst of fuel when the accelerator pedal is first depressed, reducing hesitation before the engine speeds up
- **Power enrichment circuit** - Provides extra fuel when the car is going up a hill or towing a trailer
- **Choke** - Provides extra fuel when the engine is cold so that it will start

In order to meet stricter emissions requirements, catalytic converters were introduced. Very careful control of the air-to-fuel ratio was required for the catalytic converter to be effective. Oxygen sensors monitor the amount of oxygen in the exhaust, and the **engine control unit** (ECU) uses this information to adjust the air-to-fuel ratio in real-time. This is called **closed loop control** -- it was not feasible to achieve this control with carburetors. There was a brief period of electrically controlled carburetors before fuel injection systems took over, but these electrical carbs were even more complicated than the purely mechanical ones.

At first, carburetors were replaced with **throttle body fuel injection systems** (also known as **single point** or **central fuel injection** systems) that incorporated electrically controlled fuel-injector valves into the throttle body.

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These were almost a bolt-in replacement for the carburetor, so the automakers didn't have to make any drastic changes to their engine designs.

Gradually, as new engines were designed, throttle body fuel injection was replaced by **multi-port fuel injection** (also known as **port**, **multi-point** or **sequential** fuel injection). These systems have a fuel injector for each cylinder, usually located so that they spray right at the intake valve. These systems provide more accurate fuel metering and quicker response.

When You Step on the Gas

The gas pedal in your car is connected to the **throttle valve --** this is the valve that regulates how much air enters the engine. So the gas pedal is really the air pedal.

A partially open throttle valve

When you step on the gas pedal, the throttle valve opens up more, letting in more air. The engine control unit (ECU, the computer that controls all of the electronic components on your engine) "sees" the throttle valve open and increases the fuel rate in anticipation of more air entering the engine. It is important to increase the fuel rate as soon as the throttle valve opens; otherwise, when the gas pedal is first pressed, there may be a hesitation as some air reaches the cylinders without enough fuel in it.

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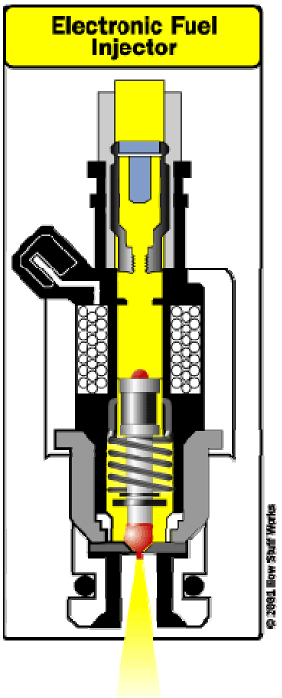
Sensors monitor the mass of air entering the engine, as well as the amount of oxygen in the exhaust. The ECU uses this information to fine-tune the fuel delivery so that the air-to-fuel ratio is just right.

The Injector

A fuel injector is nothing but an electronically controlled valve. It is supplied with - pressurized fuel by the fuel pump in your car, and it is capable of opening and closing many times per second.



Inside a fuel injector

When the injector is energized, an electromagnet moves a plunger that opens the valve, allowing the pressurized fuel to squirt out through a tiny nozzle. The nozzle is designed to **atomize** the fuel -- to make as fine a mist as possible so that it can burn easily.

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A fuel injector firing

The amount of fuel supplied to the engine is determined by the amount of time the fuel injector stays open. This is called the **pulse width**, and it is controlled by the ECU.

Fuel injectors mounted in the intake manifold of the engine

The injectors are mounted in the intake manifold so that they spray fuel directly at the intake valves. A pipe called the **fuel rail** supplies pressurized fuel to all of the injectors.

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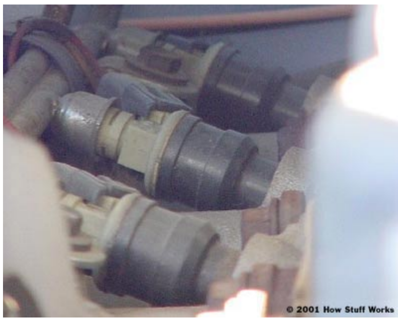

In this picture, you can see three of the injectors. The fuel rail is the pipe on the left.

In order to provide the right amount of fuel, the engine control unit is equipped with a whole lot of sensors. Let's take a look at some of them.

http://auto.howstuffworks.com/fuel-injection-quiz.htm

Engine Sensors

In order to provide the correct amount of fuel for every operating condition, the e-ngine control unit (ECU) has to monitor a huge number of input sensors. Here are just a few:

Mass airflow sensor - Tells the ECU the mass of air entering the engine

Oxygen sensor(s) - Monitors the amount of oxygen in the exhaust so the ECU can determine how rich or lean the fuel mixture is and make adjustments accordingly

Throttle position sensor - Monitors the throttle valve position (which determines how much air goes into the engine) so the ECU can respond quickly to changes, increasing or decreasing the fuel rate as necessary

Coolant temperature sensor - Allows the ECU to determine when the engine has reached its proper operating temperature

Voltage sensor - Monitors the system voltage in the car so the ECU can raise the idle speed if voltage is dropping (which would indicate a high electrical load)

Manifold absolute pressure sensor - Monitors the pressure of the air in the intake manifold.

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The amount of air being drawn into the engine is a good indication of how much power it is producing; and the more air that goes into the engine, the lower the manifold pressure, so this reading is used to gauge how much power is being produced. **Engine speed sensor -** Monitors engine speed, which is one of the factors used to calculate the pulse width.

There are two main types of control for **multi-port** systems: The fuel injectors can all open at the same time, or each one can open just before the intake valve for its cylinder opens (this is called **sequential multi-port fuel injection**).

The advantage of sequential fuel injection is that if the driver makes a sudden change, the system can respond more quickly because from the time the change is made, it only has to wait only until the next intake valve opens, instead of for the next complete revolution of the engine.