A COMPARATIVE STUDY
OF
THE EFFECT OF USE OF INFORMATION AND
COMMUNICATION TECHNOLOGY IN VARIED TEACHING
APPROACHES ON ACHIEVEMENT AND RETENTION OF
STUDENTS OF MATHEMATICS

By

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A Dissertation
submitted in partial fulfillment of the requirements for the
degree of Doctor of Philosophy in Education

Institute of Education and Research
Gomal University
D.I.Khan
2005
To

The Controller of Examinations,
Gomal University, DIKhan.

Subject: SUBMISSION OF PH.D. DISSERTATION

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ACKNOWLEDGEMENT

All the praises and gratitude are to Almighty ALLAH who endowed the researcher with the will, energy and perseverance to complete his doctoral dissertation.

Preparation of a doctoral dissertation is a strenuous and painstaking job. This requires sustainable patience, encourage and great motivation from several sides. Researcher is personally most grateful to several persons who continued to inspire him in the completion of his research project. It is not possible to list every name. However, mention is made of some pertinent ones whose guidance and motivation inspired him to complete his research assignment. Fruition of this study can be attributed to the expertise of Prof. Dr. Saeed Anwar, Supervisor of the thesis and Ex. Dean/Director of the Institute for his inspiration and dedication towards the researcher. My thanks also goes to Dr. Omer Ali, Director IER for his support and guidance. The Faculty of IER deserves appreciation for their valuable suggestions and critiques.

The researcher is thankful to external Supervisor Dr. Sabir Hussain Raja, Allama Iqbal Open University, for his suggestions, and supervising during the experiment in Islamabad. Special thanks to Prof. Dr. Mohammad Zafar Iqbal, Dean of IER, Punjab University, Lahore for his valuable comments and suggestions. Prof. Dr. Farid A. Khwaja, the Ex. Director General of NISTE deserves special thanks for his continuous encouragement and support for such a huge research work.

The researcher is also thankful to the officers, heads, teachers and students of the Federal Directorate of Education, Islamabad for giving their cooperation and participating in this research study.

A. Q. T.
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ABSTRACT

The purpose of this study was to compare and determine the more effective approach by use of Information and Communication Technology (ICT) on achievement and retention of secondary school students of mathematics in Pakistan. The three approaches used for this study were, the Computer Based Instruction (CBI), Computer Based Learning (CBL), and Teacher Centered (TC) approach. The research design was the posttest-only control group design. Seventeen research questions were put in the study. Sample of the study were 63 students and was heterogeneous to provide representation across ability level and gender. The achievement and retention instruments were in the form of researcher’s made posttest and the delayed-posttest. The CBI and CBL boys and girls students (taught separately) were grouped as treatment groups whereas the TC boys and girls students were grouped as reference group. The same topic of mathematics, “Concept of Matrices” was taught to all three groups. The CBI groups were taught through software – Educational Program of Gifted Youth (EPGY), developed by Stanford University, USA. These groups were also supported by lectures, drill, and practice and self-assessment opportunities. The CBL groups used the EPGY software and in addition they made use of all possible resources of information and communication technology; internet, e-mail, chatting and on-line help. The TC groups were taught through traditional teaching techniques. Two-way analysis of Covariance (ANCOVA) procedure from SPSS program was adapted for the analysis of data of the study. Significant levels of all research hypothesis tested in this study were at the 0.05 levels. There was no significant difference among score of the students taught mathematics through CBI, CBL and TC
approaches on achievement. The main effects of the groups and ability did not meet the 0.05 level of significance. However, the main effects comparison of gender was significant at 0.047. There was a significant difference among the group’s retention of the students taught mathematics through CBI, CBL and TC approaches. The main effect of the ability did meet the 0.05 level of significance on delayed-posttest. The main effect comparison of groups was also significant at 0.023. However, the main effect for group reach statistical significance on delayed-posttest. Post-hoc comparison using the Tukey HSD test indicated that the means score of delayed-posttest for the CBL group was significantly different from the TC group. The CBI group did not differ significantly from either of the CBL or TC groups. It was found that the CBL group had significantly scored higher in achieving as well as in retaining the content of mathematics taught to them during the experiment. The below average students retained significantly more than the average and above average students. The girls students overall scored considerably higher than the boys in delayed-posttest. It was concluded that the use of CBI approach in teaching of mathematics at secondary level in Pakistan can be encouraged for better achievement and retention of the subject which is one of the objective of teaching of mathematics at this stage.
INTRODUCTION

With the pace of time and development in the society, frequent changes have been made in the pattern of education from time to time to meet the needs of society. The remarkable progress of science and technology, and the resulting rapid progress of industry and the economy have not been only causing great changes in every aspect of society but also bringing crucial changes in education. Education is considered to be the most powerful tool for all-round development of the human beings. As such, the enlightened nations have to assign top priority to education system, which should reflect the aspirations, intentions and notions envisaged in the country and its national policy.

For better “education system”, the process of curriculum development has been crucial in socio-economic planning and setting the direction of education system at the national level. Many attempts were made from time to time to improve the national curriculum ever since the creation of Pakistan. Reports of the various education commissions, the education policies, and five-year plans have duly emphasized the need for quality education, as well as, the suitability of the structure of curriculum comparable with the advanced countries of the world and that could also meet the needs of the country (Tahir, 2004).
The newly developed National Curriculum of mathematics for secondary level has been implemented at the national level from academic year 2003. Pursuing a long-term strategy, the national curriculum is going through a series of cycle of extensive reviews, the need assessment studies, various curriculum models and curriculum development approaches (Tahir, 2004). Based on the approved curriculum, the textbooks are developed at the national level through a highly elaborate process.

The utility of mathematics made it an inevitable course of school life all over the world. But what a great misfortune with such a significant subject that the majority of our school going population is afraid of it (Susan, 1992). Why is this dread of mathematics? Whether it is due to dullness of students or it is due to callous and weak approaches of teaching of mathematics. Students who are bright and shining in almost all other subjects of their study should not be blamed for this discrepancy. The question arises: Is mathematics taught at secondary level compatible with the needs of students and in line with the prevailing boom of technology in Pakistan? Certainly not, as revealed by Sulman (1999) in his research findings on teaching methods of mathematics, “mathematics education is lacking in qualitative development and achievement level due to use of traditional methods”. Although, the textbooks elaborates the concepts logically, comprised of numbers of solved examples, illustrations and exercises, the situation of teaching of mathematics in typical schools of Pakistan is that there is no room for participation, intellectual development, exposition of incorporating derivation, and theorem-proving exercises in which students verify mathematical facts in a symbolic computation environment.
The observations made during a survey of Secondary School Reform Project of Pakistan (Government of Pakistan, 1994) have witnessed that textbooks of mathematics are taught in isolation with the world of work. The result is that students do not acquire and understand the concepts of mathematics and inquiry process but rather memorize the facts, figures, and formulae of mathematics. The purpose of mathematics education in changing society is to help children and young people acquire those understanding, attitudes, and mathematical skills that make them happy and useful citizens of the society (Susan, 1992).

Over the past twenty-five years, computers and its related technologies have influenced nearly every aspect of the developed countries of the world. The exposition in information and communication technology (ICT) has increased efforts to equip the classrooms of these countries with computers. Between 1984 and 2002, the number of computers in America's K-12 schools only increased thirty one times to more than ten million units (US Bureau of Census, 2002). Computer hardware and software has developed rapidly over the past five years in Pakistan (Government of Pakistan, 2004). The computers have become much more powerful, easier to use, smaller, and more convenient, and much more accessible. In recent years, advances such as hard disks, compact disks-read only memory (CD-ROMS), laser disk, and affordable printers have made computers much more useful for the educational process. Networking has allowed computers to be easily accessible to the teachers as well as easier for use with software packages. The Internet has increased student interest in computers and has led to an increase in student computer literacy and skills.
Research on the effects of computers on achievement began in the 1960s. Early research that has been done remained inconclusive in determining the effectiveness of computers. In a book by Skinner (1965), he felt that the use of computers could build "confidence in education" (p.19). Lumsdaine (1965) suggested that an evaluation of computer related instructions should be undertaken in many areas. These include how many students started and completed the program, average completion time, average level of performance on pre and post-tests of achievement, and the variability of these measures (p.305). More recent studies are not any more conclusive than the early studies. Baker (1999) in a study of research done on computer related approaches claims there is a lack of controlled studies. Baker found most studies were conducted by surveying students' attitudes and opinions toward computers. The survey was not conducted in an experimental fashion with a control group and experimental group. In 1997, Harold Wenglinsky of the Educational Testing Service published a major study on computers and academic achievement. Wenglinsky used data obtained from the 1996 National Assessment of Educational Progress (NAEP) mathematics examination. He found that while a positive effect of computer technology did exist, students who only used computers for all drill and practice, as opposed to using them in ways that would develop higher order thinking did worse on the NAEP test than the students who had not used the computers at all. The need for a study utilizing a control group is evident. Most of the research is qualitative or studies dealing with the differences in effect by gender and ability levels. Few studies have been conducted to demonstrate a relationship between computer related technologies and academic achievement.
Information and Communication Technology

The stunning improvements in the capabilities of computers and advances in telecommunications have produced powerful information and communication technology tools that have important implications for education in mathematics and technology. The ever-increasing sophistication in computing and telecommunications technologies has led to questions that challenge the spatial and temporal boundaries (Jonassen, 1996). Information and Communication Technology now offers the possibility for learning and teaching to take place in new settings and to inspire and facilitate lifelong education.

ICT is developing swiftly and is taking over an increasing share in every domain of life. It is among those technologies, which have got immediate acceptance and influenced a common man's pattern of life in developed and developing countries equally. The traditional classrooms lectures have been supplemented by ways and options that ICT revolution has created. The way one can access knowledge is changing, newer and newer roles of schools and those of teachers are evolving (Knowledge Net, 2000).

The ICT has become the basis of any other technology, mode of delivery, communication and interaction. According to UNESCO (2002), Information and communication technology is defined as the combination of informatics technology (technological applications of informatics in society) with other related technologies, specifically communication technology. Therefore making use of computer, Internet, websites, e-mails chatting, online programs and educational software comes under ICT.
Because of its capacity to focus on individual assessment, ICT is making the teaching and learning enterprise much more outcome-oriented, a change that has important implications for learning productivity. In fact, the areas that have made the most inroads with ICT are mathematics, and science, whose outcomes can be most easily delineated. Continuous assessment provides the data needed to map the relation between cost and benefit, thus opening the way for experimentation and innovation in the subjects like mathematics (ACTM, 1997).

In teaching, this technology empowers students to have greater control over the learning process, with all the benefits associated with active learning and personal responsibility. Not only will students decide by using ICT that when to learn and how to learn, increasingly they will also decide what to learn and how that learning is to be certified. It is in this sense that ICT “unbundles the learning enterprise from the teaching enterprise” (Massy & Zamsky, 2000). In teaching, ICT has strong potential to increase learning productivity in the areas of codified knowledge and algorithmic skills. In these specific areas, the implication is that ICT should supplement human instructors whenever possible - human intervention should be oriented mainly towards making the advantages of ICT accessible to all learners. In the case of mathematics remediation, that might mean monitoring student motivation and providing support at critical junctures to ensure that a student completes the program (Twigg, 1996).

ICT enables students to work at their own pace with continuous assessment, in contrast to the traditional teaching methods, which can be described as batch-processing with episodic assessment. Continuous assessment allows teachers to
pinpoint the areas where students falter--and in the case of some multimedia programs, those areas trigger further practice automatically so that students receive more instruction "just in time," when they need it most (Massy & Zamsky, 2000).

In Computer Based Instructions (CBI), the teaching is imparted by using the computers for delivering information to the student. This may include use of educational software, tutorials, data, graphing and self-assessment. The CBI does not include the tool usage of machines (Simonson & Thompson, 1997).

The Computer Based Learning (CBL) approach is gaining popularity to describe all student learning related to the computer. This term is considered more general because the term learning more naturally encompasses situations where the computer is used as an educational tool but is not delivering information or instructing the student (Simonson & Thompson, 1997). The tool usage of CBL differentiate its from the CBI. That is why; the CBL is not limited to students, computers and software but can also include and encompass various combinations of the computer with other technologies to create learning experiences for students. The terms computer-related technologies and the Information and Communication Technology which is very popular around the World, are basically the way of describing the hardware used in conjunction with computers.

Although, ICT has the potential to enhance teaching and learning, there is no agreement on how that technology should be used to boost academic productivity--or whether such an increase is in itself a valid goal if its enhancement means substituting technology for the more traditional, labor intensive rhythms of mathematics education. Moreover, ICT enables constructivist pedagogy; that student, learn better
by having hands-on experiences using websites, working with significant problems that challenge them and working collaboratively. It also allows students with different learning styles (such as multisensory learners versus linear learners) to learn in ways that are best for them (Twigg, 1996).

It was therefore quite imperative to look for those computers related teaching approaches, which could make the teaching of mathematics more useful, interesting and meaningful. The researcher therefore intended to see effects of use of information and communication technology on varied teaching approaches on achievement and retention of students of mathematics on a group of secondary schools students of Pakistan.

Statement of the Problem

The purpose of this study was to investigate and compare the effects of use of Information and Communication Technology in Computer-Based Instruction (CBI), Computer-Based Learning (CBL) and traditional Teacher Centered (TC) approaches on achievement and retention of students of mathematics in Pakistan.

Rationale

The effects of Computer-based instructions and Computer-based learning is important not only because of the effort and money being invested in Pakistani schools and colleges on ICT but most importantly, the great potential for increased student learning if it is proved effective. A positive relationship between the use of
the software in CBI or making use of tools in CBL approach and the achievement will indicate the need for greater implementation. The Government might see a need for increased emphasis to be placed on teacher training as well as a support of classroom usage. The results will be shared with school administration in public and private sectors to indicate if a need for more wide spread use exists. It is hoped that an increase in achievement will be a motivator to encourage more teachers to utilize CBI or CBL in teaching of mathematics as an approach of computer related technology.

Significance of the Study

The aspect of mathematics education is very crucial and demands immediate attention for the better development of mathematics teaching and the best delivery of the National Curriculum 2000 into practice in the perspectives of classroom situation. This curriculum recommends “mathematics teachers make use of various websites related with teaching learning material, methodologies, etc. of the subject, which are floated on the Internet” (Government of Pakistan, 2000). As a matter of facts, knowledge is being transferred by technology with the explosive growth of telecommunication technology and Internet (Knowledge NET, 2000).

The use of information and communication technology has sharply decreased the value of traditional algorithmic skills taught traditionally and has potentially increased the value of many areas of mathematical knowledge (e.g. probability, logic, calculus etc.), which were rarely found, or even less emphasized in the school in the pervious mathematics curriculum. Thus the question arises; would the present
delivery of mathematics in Pakistan be capable of meeting demands of our society? If not, one possible alternate can be to channelize our teaching of mathematics around ICT, which is now on the doorstep of our rural and urban students. According to the statistics of Ministry of Science and Technology, 1325 towns and villages have received access to the Internet services, which are expected to be doubled by the end of financial year 2004-2005 (COMSATS, 2004).

Continuous curriculum review in the light of the contemporary variables indicates that if mathematics education is designed to help industry, commerce, business and higher education in pure and applied disciplines then it should also address its own position and layout that helps to explore more area of research and investigation (Cockcroft, 1982). Then the question of how we can help students to construct better experience for themselves should be one of the important aspects of our mathematics teaching. What mathematics is learnt should have a sense in practicability.

One may have a balanced curriculum for learning according to the cognitive levels of the children, emphasizing on the investigational and problem solving skills that ultimately develop critical thinking among the pupils. CBI and CBL approaches supported with suitable software can be used to make reliance on the notion of “Mathematical Power” – the ultimate goal of the subject i.e. HOW? WHAT IF? PREDICT, TEST and hence GENERALIZE (Susan, 1992). Therefore an innovative support to teaching of mathematics is a question in the light of present boom of information and communication technology in the country.
No mathematics program can be more successful than its implementation in the classroom. A mathematics program can be more effective, productive, and interesting if it is supported by interactive activities, exposition, real world situation, and diagnostic examples (NRC, 1985). Accordingly, the success of any mathematics programs mostly depends upon the following elements:

i. Delivery of mathematics showing promise for developing better quality of learning and retention;

ii. Opportunity for exposition and understanding in every day life;

iii. Students of mathematics recognize and apply knowledge and skills of mathematics in the world of work;

iv. Room for development of personalized learning and guidance;

v. Search for any support to teaching, which actually supplant rather than primarily augment the traditional means of delivering the content of mathematics (Massy & Zamsky, 2000);

vi. Substituting technology-based programs for traditional teaching methods comprise something essential.

These elements are needed to be considered at the stage of implementation of any curriculum of mathematics. Support is clear from the “Curriculum 2000” for teaching and learning mathematics by making use of information and communication technology at the secondary level (Govt. of Pakistan, 2000). However, there was a need to verify these results in a totally different situation and Pakistani society where the system of education is entirely different from the environment of the developed
countries in which these experiments are carried out. Therefore, this study provided an ample opportunity to search for use of ICT in teaching of mathematics in Pakistan.

Objectives of the Study

The following were the objectives of the study:

1. To compare the effects of use of Information and Communication Technology using CBI, CBL and TC approaches on achievement of students of secondary school mathematics.

2. To compare the effects of use of Information and Communication Technology using CBI, CBL and TC approaches on retention of students of secondary school mathematics.

3. To find out more effective approach of teaching mathematics from CBI, CBL and TC approaches for the secondary schools students.

Assumptions

In carrying out the study, it was assumed that:

1. Different approaches of teaching mathematics at secondary level effect on the achievement of the students.

2. Different approaches of teaching mathematics at secondary level effect on the retention of the students.
3. Different approaches of teaching mathematics at secondary level have differential effects on the achievement of the students belonging to different ability level and gender.

4. Different approaches of teaching mathematics at secondary level have differential effects on the retention of the students belonging to different ability level and gender.

**DELIMITATIONS**

Following were the delimitations of the study:

1. The study was delimited to two Federal Government schools of Islamabad. The results can be generalized to other settings.

2. The effects of three selected teaching approaches of mathematics were delimited to two attribute variables i.e., the ability level and sex of students only.

3. It was not possible to select the sample from all sections of 9th classes of each selected school. The selected schools are the biggest schools of Islamabad and it was not possible for school administration to change and disturb the ongoing schedule of their schools for this study. It was therefore decided to take one full section using basket technique from each of the school for the experiment.

4. The computer skills of the students were not equal due to different socio-economic background and access to Internet clubs.
5. The experiment was conducted in computer laboratory of sampled schools for the CBI and CBL groups. However, some short and necessary computer related equipment was made available to meet the required specifications of software and programs used while teaching through CBI and CBL approaches.

6. Due to revised scheme of studies for secondary schools and tight schooling schedule, it was not possible for school’s administration to spare the students for the period equivalent to three weeks and for more than one chapter of their course of mathematics.

Research Questions

The design of the study permitted to investigate the following questions:

**Question on Achievement and Retention**

AR Is there a difference on mean score among the achievement and retention of the students of secondary level taught mathematics through CBI, CBL and TC approaches?

**Questions on Achievement – Posttest**

A1 Is there a difference among the achievement of the students of secondary level taught mathematics through CBI, CBL and TC approaches?

A2 Is there any significant interactions (of achievement) among the types of teaching approaches (CBI, CBL and TC), students’ ability (below average, average and above average) and gender (boys and girls)?
A3 Is there a difference among the achievement of the students of secondary level taught mathematics through CBI and CBL approaches?

A4 Is there any significant interactions (of achievement) among the types of teaching approaches (CBI and CBL), students’ ability (below average, average and above average) and gender (boys and girls)?

A5 Is there a difference among the achievement of the students of secondary level taught mathematics through CBI and TC approaches?

A6 Is there any significant interactions (of achievement) among the types of teaching approaches (CBI and TC), students’ ability (below average, average and above average) and gender (boys and girls)?

A7 Is there a difference among the achievement of the students of secondary level taught mathematics through CBL and TC approaches?

A8 Is there any significant interactions (of achievement) among the types of teaching approaches (CBL and TC), students’ ability (below average, average and above average) and gender (boys and girls)?

Questions on Retention – Delayed Posttest

R1 Is there a difference among the retention of the students of secondary level taught mathematics through CBI, CBL and TC approaches?

R2 Is there any significant interactions (of retention) among the types of teaching approaches (CBI, CBL and TC), students’ ability (below average, average and above average) and gender (boys and girls)?
R3 Is there a difference among the retention of the students of secondary level taught mathematics through CBI and CBL approaches?

R4 Is there any significant interactions (of retention) among the types of teaching approaches (CBI and CBL), students’ ability (below average, average and above average) and gender (boys and girls)?

R5 Is there a difference among the retention of the students of secondary level taught mathematics through CBI and TC approaches?

R6 Is there any significant interactions (of retention) among the types of teaching approaches (CBI and TC), students’ ability (below average, average and above average) and gender (boys and girls)?

R7 Is there a difference among the retention of the students of secondary level taught mathematics through CBL and TC approaches?

R8 Is there any significant interactions (of retention) among the types of teaching approaches (CBL and TC), students’ ability (below average, average and above average) and gender (boys and girls)?

Methodology

The methodology was designed to collect data required to achieve study’s objectives. The research design envisaged collection of data using various resources, techniques and role of teachers for the treatment of different groups. A summary of research methodology used for this purpose is given as below:
Table 1

Summary of Research Methodology

<table>
<thead>
<tr>
<th>Group</th>
<th>Resources</th>
<th>Techniques</th>
<th>Role of Teacher</th>
<th>Instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBI</td>
<td>Textbook</td>
<td>Interactive, Cooperative</td>
<td>Guided</td>
<td>Posttest, delayed-posttest</td>
</tr>
<tr>
<td></td>
<td>Computer</td>
<td>Self-pacing</td>
<td></td>
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<td></td>
<td>EPGY software</td>
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<td></td>
<td>Multi-media</td>
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<tr>
<td>CBL</td>
<td>Textbook</td>
<td>Self-pacing, Searching</td>
<td>Facilitator/ Navigator</td>
<td>Posttest, delayed-posttest</td>
</tr>
<tr>
<td></td>
<td>Computer</td>
<td>Use of internet</td>
<td></td>
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<tr>
<td></td>
<td>EPGY software</td>
<td>Use of e-mail</td>
<td></td>
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<tr>
<td></td>
<td>Multi-media</td>
<td>Chatting</td>
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<tr>
<td></td>
<td>Telephone</td>
<td>On-line help</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC</td>
<td>Textbook</td>
<td>Chalk and Talk</td>
<td>Centered</td>
<td>Posttest, delayed-posttest</td>
</tr>
</tbody>
</table>

Population and Sample

The population of the study included the students from two different schools from Islamabad. The sample of this study was heterogeneous to provide representation across ability level and gender.

The 63 students selected for this study were divided into three groups separately the boys and girl’s sections into treatment group 1 and treatment 2 and reference group. The treatment group 1 was identified as those, which received instructions of mathematics through Computer Based Instructions (CBI) approach. The treatment group 2 was identified as those, which received instructions through Computer Based Learning (CBL) approach. The trained mathematics teacher taught
these groups. The reference group was defined as those using the traditional teaching
- Teacher Centered Approach in mathematics classrooms. A mathematics teacher
who was ignorant in use of ICT taught this group.

**Instruments**

The marks obtained in the subject of mathematics in the final examination of
class VIII were used to randomly assign students of matched pairs to CBI, CBL and
TC groups. The instrument, which was used as post-test of this study, was developed
from the selected chapter of textbook of mathematics Classes IX-X. This instrument
went through jury validation.

The achievement and retention instruments were in the forms of the posttest.
A table of random numbers was used to randomize the sequence of the questions of
the posttest (achievement) and delayed posttest (retention). Changing the sequence of
questions and the time interval between the administrations of the tests reduced
student sensitization to the instruments.

**Procedure**

The chapter on “Concept of Matrices” of mathematics textbook for Classes
IX-X was selected for instructions to the treatment groups and the reference group
with the exception of use of ICT. Only the treatment group 1 and 2 made use of ICT
respectively.
The overall performance in final examination of class VIII was the criteria for grouping the students into the category of below average, average and above average. The boy and girls' school students were separately grouped and given treatment in their respective schools. The posttest was given one day after the completion of the treatment. Four weeks subsequent to the posttest, the delayed posttest was administered to measure student retention of the concepts and understanding attained on the topic.

*Treatment Group-1*

The CBI groups was taught the topic by making use of software – Educational Program for Gifted Youth (EPGY), lectures, and hands on opportunities for self-assessment questions, drill and practice on computers.

*Treatment Group-2*

The CBL group's students also used the EPGY software. In addition, they utilized computer based technology resources; including internet, e-mail, chatting and on-line help on the topic of matrices.

*Reference Group*

The reference group was taught the same topic form the textbook for the same period but through Teacher Centered (TC) approach. The students of this group were
given chance and time for interaction, questioning and what else being practiced in our schools but without using any component of ICT.

Data Analysis

The data was collected from the instruments used in the study. The data was analyzed and compared the effect of the treatments and reference groups, ability, and gender on achievement and retention scores.

Two-way analysis of Covariance (ANCOVA) procedure from SPSS program was used to analyze the data. The ANCOVA Procedure was used for two reasons. First, selection and through randomization of students for the purpose of dividing them into three groups on the basis defined was not possible. Second, the use of covariant procedure mathematically controlled for the covariate (the posttest), so that the group main effect could be interpreted more easily. The ANCOVA procedure also determined two-way interactions. Post-hoc test (Tukey test) was applied on delayed-posttest for the purpose of comparison of mean score of groups.

Significant levels of all research hypotheses tested in this study were set at the .05 levels.
### Definition of Terms

**Computer Based Instruction Group**  
Boys and girls of all ability levels who were taught the selected topic of mathematics through Computer Based Instruction approach.

**Computer Based Learning Group**  
Boys and girls of all ability levels who were taught the selected topic of mathematics through Computer Based Learning approach.

**Teacher Centered Approach Group**  
Boys and girls of all ability levels who were taught the selected topic of mathematics through Teacher Centered Approach.

**Information and Communication Technology**  
Combination of informatics technology with other (communication etc.) related technologies.

**Mathematics**  
The subject of mathematics taught as compulsory subject at secondary level.
REVIEW OF RELATED LITERATURE

The Mathematics Education

The Mathematics Curriculum in Pakistan

Mathematics is compulsory subject up to secondary level in Pakistan. According to the Curriculum Document (2000), and the scheme of studies, the subject of mathematics is taught at grade IX and X. The total numbers of periods per week in a school are 92 and the periods allocated to mathematics per week are 12 which is 26% of total school work load. The numbers of school days are about 180 in an academic year and an average school day is six hours. This time is not quite viable as compared to the developed countries such as U.S.A, Germany, Japan whose school days in a year ranges from 175 to 220. The average length of school stay varies from 5 to 8 hours per day (ISESCO, 1989).

The mathematics curriculum for secondary level has gone through number of revisions since the creation of Pakistan. The first change in mathematics curriculum was initiated during 1968. This change was termed as modernization of curriculum and included drastic changes in mathematics subject matter, textbooks and teacher training. For the first time in Pakistan, the “Sets” were introduced at secondary level.
The greater emphasis was placed on the practical and scientific application of mathematics (Government of Pakistan, 1968).

A massive revision of secondary school mathematics was carried out during 1972-73 (Government of Pakistan, 1972). In this revision, the content was made concept oriented. In addition to this, deductive and inductive approaches were adapted for teaching mathematics to the students of secondary classes. The textbooks were implemented from year 1977. Secondary school mathematics curriculum was also revised in 1986 but only a few and minor changes were made in the pervious curriculum (Government of Pakistan, 1986). This curriculum was implemented from the year 1988.

A major breakthrough in the history of development of mathematics curriculum for secondary level came in the year 1994 when a unified curriculum was developed for all the students opting general as well as elective group (Government of Pakistan, 1994). This curriculum was divided into four major categories viz: Sets and Numbers, Algebra, Geometry, Trigonometry and Information handling. This curriculum was implemented from the year 1995. The curriculum was implemented without any planning and strategy especially towards the delivery of mathematics and in the face of shortage of mathematics teachers, which has always existed. The findings of an evaluation study (Tahir, 1997) conducted at NISTE, Islamabad on this curriculum revealed that most of the portion of this curriculum was taken from the earlier curriculum made for the students of elective group. The clientele of general group has no option but to study this curriculum. Moreover, the teachers who were been teaching general mathematics, without any preparation, had to teach this course.
Most of the teachers especially the female did not prove capable of teaching. The comparison of curriculum of 1994 with that of 1986 reveals that it was quite close to that of 1986. However, the only significant changes introduced in the curriculum of 1994 are the inclusion of information handling.

This decision effected the achievement of students in the examination. According to the Gazette notification of Board of Intermediate and Secondary Education (BISE), Islamabad for the year 2002, 75% of the failing total students failed due to the failure in the subject of secondary school mathematics (BISE, 2002). Similarly, in BISE, Rawalpindi, 80% of the unsuccessful students failed in the Secondary School Examination due to failure in mathematics in the year 2002 (BISE, 2002).

In an attempt to overcome the weaknesses of the existing national curriculum for mathematics, the Punjab Education Department (PED) has developed the science and mathematics curriculum for Classes I-XII (Government of Pakistan, 2000).

The Government of Punjab, Education Department formed a Task Force consisting of four groups of physics, chemistry, biology and mathematics for revision of the curriculum and development of textbooks and teaching aids for Classes I-XII. These four groups took up the task assigned to them in December 1999. The major objective of this task was to modernize the curriculum for mathematics and science subjects, so that they were in accord with the developed world in content and approach. The initial draft of these curricula was developed by the Task Force of the PED and then sent for comments to the other three provinces and the Federal Government.
The Provincial Curriculum Bureaus, Textbook Boards, the National Institute of Science and Technical Education (NISTE) and the Curriculum Wing, Ministry of Education designed the final curriculum of mathematics and science subjects. The Federal Ministry of Education has approved this curriculum. This curriculum has been implemented from academic year 2003.

The analysis of present mathematics curriculum for Classes IX-X when compared with curriculum of 1994 revealed that no crucial change has been introduced in this curriculum rather this is close to the curriculum of 1986 (NISTE, 2000). Nevertheless, the sequence of some of the topics in a few chapters of this curriculum is different, whereas, chapter such as “information handling” has been heavily extended. However, the most important among the salient features of this curriculum is the grass root change towards the delivery approach of mathematics. The main thrust on the curriculum of mathematics for Classes IX-X is the acquisition of information and skills necessary to become sensible and responsible individuals in highly technological society of the 21st century.

Delivery of Mathematics

Teacher having poor mathematics knowledge both in contents and methodology areas are not able to contribute positively to the successful delivery of the subject. Even if a teacher is capable in content area but not in delivery system then his teaching strategy would remain a mismatch. Unfortunately, any curriculum change which put mathematics teachers in trouble is usually left by them mostly they
leave the newly introduced topics untouched. Most commonly left out topics at secondary level which exists since long, are the (i) concept of Function and Mapping (ii) exercises of Theorems; (iii) the Practical Geometry and (iv) Concept of Matrices. Many teachers during teacher training were inquired about it. They regretted their inability to understand and hence its delivery to the students. Similarly, teachers feel handicap while solving the problems related to the theorems and of practical geometry. Indeed there are many more factors which were observed while examining delivery of mathematics education during an appraisal study (NISTE, 1999).

**Secondary School Mathematics Teachers**

Mathematics teachers at secondary level in Pakistan are, by requirement, mathematics graduates with Bachelor degree in Education (B.Ed). Shortage of qualified mathematics teachers is a worldwide phenomenon and Pakistan is no exception (Anderson, 1998). Secondary schools in disadvantaged areas are particularly deficient in mathematics teachers. The result is that less qualified teacher and sometimes-unqualified teachers are entrusted the work of mathematics teaching (Bhatti, 1987), which is detouring the whole system of education.

Even the graduate mathematics teachers are not fully qualified due to many academic and non academic reasons, the prominent being selective study of mathematics subjects at Higher Secondary and Graduate level. Another reason is that the science teachers at Graduation level (B.Sc) themselves are educated in two of the science subjects; mathematics and physics, physics and chemistry or chemistry and
biology, while they are mostly required to teach all the science subjects at secondary level. Even during B.Ed. training, the prospective teachers are prepared to teach only two science subjects. Hence many who teach mathematics have received no training in teaching of mathematics (Government of Pakistan, 1998).

**Professional Competency of the Mathematics Teachers**

The aspect of Mathematics Education is very crucial and demands immediate attention for the better development of Mathematics teachers and better delivery of the National Curriculum Policy into practice in the perspective of classroom situation. This can be done through strengthening use of some innovative techniques. Teaching strategies particularly in Mathematics education, such as exposition and discussion practical work, problem solving, investigation work, drill works and motivation need to be supported by some technology, which is on the doorstep of Pakistan nowadays. This would indeed help both teachers and students to develop mathematical power and habit of how to mathematize a given situation (Harries, 1986).

**Issues of Mathematics Education Around the World**

Mathematics education is leading agent to promote basis for business, industrial, agriculture, and scientific research in a country. Each of these has a strong influence on social development. For development, we are in great need of persons who are imbued with the scientific spirit of curiosity and inquiry, combined with a
their environment, carried along by a constantly inquiring mind and reinforced by the ability to identify and solve problems arising from the needs within this environment.

One of the problems in developing countries is the non-availability of skilled persons in different fields of life. In a study of UNESCO (1990), it is indicated that “Many schemes exist for the transfer of technical knowledge, but most of them suffer from a lack of suitably skilled recipient at all level in the developing countries... We endorse this view, and sell the creation of right environment with in which new technologies can take root and grow as a vital step in the developing process. The two essential elements in this environment are trained manpower and informed public – depend upon a strong educational system”.

These essential elements are discussed in another study undertaken by UNESCO (UNCST, 1997). “Education must also prepare the practitioners of science and technology in different discipline at the various levels – scientists, engineers and technologists”. In Pakistan according to National statistics, 73% students are those
who terminate their formal schooling at secondary level (Government of Pakistan, 1999). Therefore, the main problem of curriculum in mathematics education is those of relevance, objectives and delivery. It looks quite imperative to make use of those technologies for the delivery of contents and mathematical phenomena, which fulfill the needs of this level.

One of the increasing trends in developing countries is moving toward making their education systems, available and relevant to the whole society. The Science, Technology and Society (STS) Approach is more conspicuous in their mathematics education. The mathematics education in these developing countries are now emphasizing on the use of information and communication technology (ICT) in their curriculum (Haefner, 2000).

A number of research studies have investigated the effectiveness of mathematics curriculum in accomplishment of these objectives in developed countries (Massy & Zamsky, 1995). The new mathematics curriculum developed in the USA during the period of 1990 to 2001 were quite different from earlier in the sense that;

- The teaching methodologies and strategies advocated in these are based upon the most updated theories of, how children learn mathematics?
- The new mathematics program emphasized exposition of mathematical problems and theorems while focusing on the current concepts in mathematics. Thus higher cognitive skills are emphasized in these curricula.
- The traditional mathematics courses had emphasized knowledge of mathematical facts, laws and theories.
There is realization that the basics goals of mathematics education are not only reading and acquiring the algorithmic skills but rather it must include communication and higher problem skills as well as information technology as thinking tools that will allow our students to understand the technologies on their footstep and around the world.

Theories Supporting Use of Information and Communication Technology in Education

Several theories have been the basis for investigating the effect of information and communication technology in the teaching and learning process. Most of the techniques applied to the design and use of CBI and CBL can be traced to one of these theories. Behaviorism, systems theory, and cognitive theory will be discussed in this section with an emphasis on how each provides direction to the design, use, or effect of information and communication technology in education.

Behaviorism

Of the theories supporting computer use in education, behaviorism has historically had the greatest influence. Behaviorism was used as the basis for designing early CBI and was also the impetus behind many related teaching strategies, such as the use of teaching machines and programmed texts. Thorndike's connectionism, Pavlov's classical conditioning, and Skinner's operant conditioning
were theories that directed early researchers who examined the effect of CBI on behavior (Skinner, 1954; Thorndike, 1969).

Applications of behaviorism in education are based on the principles that instruction should be designed to produce observable and quantifiable behavior in the learner. Behaviorists expect any instructional activity such as computer-based tutorials to change the students in some obvious and measurable way. After completing a lesson student should be able to do some thing that they could not do or could not do as well, before the lesson. Using behavioral objectives is one technique advocated by behaviorists that many educators have found to be very effective. Behavioral objectives are easy to develop and have been related to improvement in student achievement.

The Thordike’s connection theory stated that learning was based on a series of associations, or connections, between the problems of a particular situation and what had been accomplished previously. Complex ideas such as “functions” a concept of mathematics should be broken into related sub-concepts that need to be applied and understood by the students in Bloom’s Taxonomy. Therefore, the establishment of specific goals for teaching, the expectation that goal related changes could be measured, and the idea that large tasks should be subdivided into simpler ones became basic concepts of behaviorist thought. These ideas are also used extensively in the design of CBI.

Ivan Pavlov’s (1927) research was the second area of interest for learning theorists in the first half of the 20th century. Pavlov’s high order conditioning is the result of building complex chains of stimuli that control behaviors. The most
important educational and Computer Based Learning (CBL) consequence of his work was that it served as the basis for attempts to promote the idea that the learning process should be organized from very simple to very complex events.

The theorist most closely associated with behavioral theory is B.F. Skinner. He did more to popularize this theory than anyone else, primarily because of his interesting research, but also because of his flair for publicity.

Skinner viewed the study of learning as a science, and he looked to the same model for investigating events that Pavlov used. He was said to have stated that other learning psychologists gave no glimpse of experimental method but that Pavlov did. Pavlov controlled the environment so he could see order in behavior. Because of this orientation, Skinner viewed learning as the change in behavior that was observed under properly controlled situations.

Skinner believed there were two types of learning. The first was Pavlov's classical conditioning, where a stimulus was applied to an organism to produce a response. Learning would occur when there was a transfer of stimulus control for a response from one stimulus to another stimulus.

The second kind of learning, and the category most often associated with Skinner, is called operant conditioning. This approach for producing behavior change uses no identifiable stimulus before a response, but rather uses reinforces that follow a response or that are produced by a response. These reinforces are responsible for a behavior change. Operant conditioning involves the use of reinforcement to promote desirable changes in behavior, and this reinforcement occur following desired actions.
For example, a mathematics teacher might have students participate in a series of organized problem solving exercises. The first few activities might be computer lessons that permit little student variation but that praise the student for correct answers. These computer lessons would give cues to students to ensure success. Later, as students become more knowledgeable and confident, the cues would be gradually removed so that in later problem solving exercises students could work on their own.

In this case, the mathematics students would be conditioned to correctly complete sequential techniques by the reinforcement contained in the computer lessons so that eventually they would use these techniques without the need for prompting.

Skinner's contributions to educational practice, and to CBI, are numerous. They include the following techniques:

- Stating objectives in terms of desired outcome behaviors.
- Assessing a student's previously acquired behaviors before any instruction.
- Placing learners in a sequence of instruction where they can achieve at the 90% level, but before new instructional activities where they would not be this successful.
- Using teaching machines to reinforce and to strengthen desired behaviors.
- Recording a learner's progress through a lesson to gain feedback for revising the lesson.
**System Theory**

In its broadest conceptualization, systems theory concerns the organization and structure of entire organisms. A biologist, Otto von Bertalanffy (1968), is credited with stating the theoretical foundation of systems theory. This foundation is based on the scientific exploration of “wholes” and “wholeness” and on the study of their structure and stability. Systems theorists state that events should be studied in relationship to other events. These relationships should be identified and their effect be measured.

The systems approach is a kind of “Cookbook” or procedures for designing instruction. The systems approach is based on the following ideas:

- The systems approach applies to learning a method of logical problem solving similar to the scientific method.
- Instruction designed using the systems approach is self-correcting and uses logical methods of decision making.
- Instruction developed using the systems approach applies rational procedures for reassignment of specific behavioral objectives.
- The systems approach incorporates ways of looking at complex organizational problems that take into account contingencies.

The systems approach for instructional design is behaviorally oriented. It strongly advocates the application of behaviorist principles such as pre-assessment of the target audience, use of objectives stated in terms of expected outcomes, and use of feedback. The system approach to instructional development is actually a series of
steps that guide the developer of instruction including CBI. The three-parted instructional development model has some functions, which provide the instructional developer with additional procedures to follow when CBI is designed.

Systems theory, the systems approach, and the instructional development model give considerable guidance to educators interested in designing or evaluating CBI (Dick & Carey, 1990). Preplanning, audience assessment, feedback, interaction between elements of the system (student and lesson) and use of performance-based objectives are techniques that have been derived from systems theory that are routinely used to develop CBI. Systems theory gives educators a prescription for designing effective computer lessons, and although not universally applicable, it does provide considerable direction to educators interested in differentiating between ineffective materials and techniques and those likely to be more successful.

**Cognitive Theory**

Educational psychologists and learning theorists are moving away from the behaviorist approach and have advocated a closer look at the internal processes that occur in learners during instruction. Behavioral psychologists generally ignore the cognitive changes that mentally occur during teaching and maintain that it is impossible to design instruction on changes in a learner's brain because these changes are not observable, not measurable, and are impossible to predict. On the other hand, cognitive psychologists, a common name for advocates of cognitive theory, attribute a greater degree of autonomy and initiative to the learner (Bruner, 1960; Carey, 1986; Hilgard & Bower, 1975).
Cognitive theory concentrates on the conceptualization of students learning processes. It focuses on the exploration of the way information is received, organized, retained, and used by the brain. Proponents of cognitive theory believe instructional design should take into account the cognitive structure of the learner, and of groups of learners. Several people have been influential in advocating the cognitive approach, including Jerome Bruner, Jean Piaget, and Seymour Papert.

Many consider Bruner (1960) the primary early advocate of cognitive theory. He has proposed that much of behavior depends on how we structure knowledge about ourselves and the world around us. Cognitive theorists believe instruction must be based on a student's existing state of mental organization, or schema. How knowledge is internally structured or organized by a student has considerable effect on whether new learning will occur. Some have hypothesized that students with a dominant left hemisphere of the brain process information more sequentially and logically than do students who have a dominant right brain hemisphere (Carey, 1986). In other words, CBI needs to be organized and delivered in a way that complements the cognitive structure and level of sophistication of the learner. Where behaviorists were concerned with the outcomes of instruction, cognitive scientists are more interested in the content of instruction.

Hypermedia, a computer based instruction approach that is nonlinear and consequential, is a powerful tool being used by cognitive scientists to examine how students interact with instruction during the process of learning. The way students use hypermedia, gives insights into the structure of thinking and how learning occurs.
Burner and other cognitive theorists focus on several concepts (i) how knowledge is organized and structured, (ii) readiness for learning (iii) intuition, by intuitions, Bruner means the intellectual techniques used for arriving at plausible but tentative conclusions without going through a series of analytical steps. In other words, the value of the educated guess is recognized. Last, the importance of motivation, or desire to learn, is identified. Specifically, cognitive scientists accept the importance of students having positive attitudes towards learning.

Cognitive theory gives educators interested in designing or evaluating CBI several guidelines.

1. Predisposition to learning is important. Instruction needs something to get it started, something to keep it going and something to keep it from being random. Bruner (1960) would call this activation, maintenance, and direction.

2. The structure and form of knowledge must be considered. Specifically, the body of material to be learned should be organized in some optimal way. Cognitive theory is partially based on the concept that children are first able to understand concrete operations, then graphic representations, of reality, and finally abstract verbal and numerical symbols. Dale (1946) formalized this concept with his Cone of Experience, which organized experiences in 12 levels of increasing abstraction. Dale stated that before learners can understand abstract experiences they required a sufficient depth and breadth of more realistic experiences they required a sufficient depth and breadth of more realistic experiences. Children cannot understand a computer generated
drawing of a “square” unless they have first experienced “square” shaped thing.

3. Sequencing of instructional material is important. Cognitive theory is based in part on the idea that there is an optimal sequence for presenting educational experiences. Sequencing must take into account the limited capabilities of learners to process information.

4. The form and pacing of reinforcement must be considered. Learning depends a great deal on knowledge of results at a time and place when that information can be used. For example, “quadratic equations” should not be taught before “linear equations” structure is learned. Feedback should be directed toward what is appropriate, not what is inappropriate.

5. Discovery learning is one important technique that incorporates much of cognitive theory. Discovery learning consists of inserting learners into educational situations without telling the student what is already known about that situation. The assumption is that with minimal help from the teacher the student will learn more by discovering the lesson found in the situation. Papert’s (1980) LOGO language is an excellent example of a computer based tool often used to teach problem solving by discovery learning. Hypermedia is an example of computer-based instruction that gives students the opportunity to explore a lesson in a way that is most appropriate for them.
Constructivism and Situated Cognition

Recently, constructivism and situated cognition have captured the attention of teachers and computer education specialists. Most consider these two models directly related to cognitive theory, but they have interesting implications for the design and use of computer-based instruction. Constructivism is founded on the belief that there is a real world that is experienced but that the person imposes meaning and understanding of the world.

There are many ways to structure the world, and many perspectives of an event or concept. Learners construct their own meaning from instructional activities. Meaning is rooted in and indexed by experience. Each experience with an idea and the environment of the idea becomes part of the meaning of that idea. The experience in which an idea is embedded is critical to the individuals understanding of an ability to use the idea. Most constructivists believe the experience with concepts and ideas in school are quite different from the experience with those concepts in the real world. Constructivists emphasize situating cognitive experiences in authentic activities.

Situated cognition, or situated learning, occurs when students work on authentic tasks in a real world setting. It does not occur when students are taught de-contextualized knowledge and skills (Brown, Collins & Duguid, 1989). This implies that effective instruction should be based on authentic tasks that permit the student to construct a learning environment meaningful to them. Students do not discover knowledge they construct it in authentic settings.

Constructivist and situated cognition principles are causing educators to rethink computer-based learning. First, learner control and use of authentic
information are critical to effectiveness. The lesson must be flexible and rich in content, so students can draw on many stimuli to construct knowledge. Second, use of multimedia that includes still visuals, graphics, motion segments, visual mnemonics, and sound is important. Computer-based instruction should allow students to receive stimuli from a variety of sources and in many different ways.

Currently, there is more theorizing about constructivism and situated cognition by computer educators than actual application. This almost certainly will change as design models become more sophisticated and as powerful multimedia computers become more widely available.

**Implications of Theories**

A theory base has two important purposes. First, theories provide a direction to research. Theories are based on research results, but they are not static. They continue to evolve as new research findings are reported. In other words, theories are used as guides for researchers who continue to examine what the theories imply in an attempt to clarify them. Ultimately, scientists strive for the development of laws that can be accurately and widely applied to solve problems.

Second, theories provide direction to the practice of a profession. Specifically, behaviorism, systems theory, cognitive theory, constructivism, and situated cognition guide developers, of CBI. They also give teachers a sound basis for evaluating materials developed by others. Traditionally, behaviorism and systems theory have been the primary theories used to support the application of computer to learning.
Increasingly, however, cognitive science with its many subcategories and adaptations such as Schema theory, constructivism and situated cognitional has demonstrated relevance to those who study CBI.

A similarity of described theories is the importance of individualized instruction. Individualization seems to be the most logical method of instruction, based on what these theories say. Group instruction can be designed based on any or all of these theories, but individual instruction seems to be a powerful method of teaching. Certainly CBI, which usually is individualized, is the most logical method for differentially applying to students the techniques advocated by these three theories. Only individual tutoring by a teacher would be more effective. Recently, however, collaborative learning advocates have proposed a redesign of some kinds of computer-based instruction so students work in learning groups and collaborate with others even when using computers.

**Uses of Computer Software in Education**

As Papert (1980) suggests, discovering the appropriate uses for the computer in education has been a problem. Few deny the enormous educational potential of this machine, which can handle data with amazing speed and accuracy and is beginning to simulate human and thought and behavior, but most seem to agree that we have yet to tap all the possibilities of the technology. In this section, general categories for computer software used in the schools will be presented.
Trends in Computer Software

Authors of the OTA – Office of Technology Assessment (Porto, 1988) report reviewed research about computer in education and suggested that the total research in the area created an incomplete and somewhat impressionistic picture. The report suggested, however, the following areas as the most promising current uses of computers in education:

- Drill and practice to master basics skills
- Development of writing skills
- Problem solving
- Understanding abstract mathematics and science concepts
- Simulation in science, mathematics and social studies
- Manipulation of data
- Acquisition of computer skills for general purposes and for business and vocational training
- Access and communication for traditionally un-served populations of students
- Access and communication for teachers and students in remote locations
- Individualized learning
- Cooperative learning
- Management of classroom activities and record keeping

There now seems to be consensus that the computer can best be used in classrooms to help students develop information handling and problem solving skills in the subject like mathematics. Tool software, problem solving software,
simulations, and hypermedia environments are all types of computer use that emphasize these goals. These uses of computer in classrooms will not eliminate other effective uses of the tool, however.

**Drill and Practice**

One of the first uses of other computer in education was for drill and practice in arithmetic and reading. As early as 1968, Patrick Suppes and Richard Atkinson of Stanford University were producing computer programs that elicited a student response, provided immediate feedback, and then proceeded to another problem. In the Suppes Atkinson model, the computer presents students with randomly generated problems of a specific type, and students stay with that type of problem until they achieve a certain level of proficiency. Students then move to problems of a more difficult or different nature (Atkinson & Suppes, 1968).

Drill and practice computer software has remained popular and has been widely produced for most subject areas. Although the Stanford work of the 1960s was done on time-sharing mainframe computers, the drill and practice model was widely adopted when the microcomputer became available in the late 1970s. In fact, before 1984, about 75% of all educational software produced was of the drill and practice variety.

In the mid 1980s, numerous computer educators began to criticize the overuse of drill and practice programs in education. They suggested that drill and practice was not a good use of the power of the computer and that much of what was being sold as drill and practice software could be done just as easily in workbook or on a “ditto.”
These critics also said that by emphasizing the use of drill and practice activities, educators were using the computer to encourage the teaching of problem solving skills. One presenter at a Minnesota Educational Computing Corporation Annual Conference reacted to the vehement criticism by titling her talk “Drill and Practice is Not a Dirty Word.”

Today’s drill and practice programs are much more sophisticated. Milliken Publishing Company has produced a mathematics series that has been widely accepted in the schools. In the program, children are tested before beginning the program and placed at the appropriate level. They then proceed through the program, mastering each level before they are allowed to go on.

*Advantages of Computerized Drill and Practice*

While drill and practice is not the only use for the computer in education, it has several advantages over traditional methods.

1. *Immediate Feedback*

   Probably the most obvious advantage of computer drill and practice is that students receive immediate feedback on their responses. There is no waiting for the teacher to grade the paper. Students do not “practice their mistakes” because they are alerted the first time they make an error. This contrasts with a student doing worksheet type drill and practice that might make the same mistake 25 times until feedback from the teacher is received.
When using a quality drill and practice program, students can progress at their own speed. The program determines when a student has mastered a concept and then places the student in the next higher level. Students doing paper and pencil drill and practice frequently do more (or fewer) items than necessary for master of a concept. In computer assisted drill and practice, the program determines the optimum number of items for each student.

A quality drill and practice program need not respond just that a response is right or wrong, it can also give individual feedback about the types of mistake made by the student. Thus, if a student responds that 62-19 is 47, the program can point out that the student has subtracted the bottom number from the top number and explains why this cannot be done.

More sophisticated error-analysis techniques have become available that have been adapted from work in the area of artificial intelligence and involve the ability of the computer to “understand” student errors. ICAI (intelligent computer aided instruction) is a term used to describe software programs that incorporate artificial intelligence. The type of immediate individualized error analysis available in sophisticated drill and practice programs is almost impossible for the typical teacher to provide.

b. Efficient Record Keeping

Most new drill and practice programs contain fairly sophisticated record keeping functions. With these functions, information is kept on the progress of each student in a class. At any time, the teacher can access these records and determine at
which level the student is operating the amount of time the student has spent on the program, or specific concepts that have been difficult or easy for the student.

c. Motivation

Many computer drill and practice programs appear more motivating for students than typical workbooks or teacher made worksheets. The use of graphics and sound, the motivation of immediate feedback and the novelty of working on the computer are all factors that may increase time on task for students performing drill and practice activities. Research results on this topic are mixed, however, and some studies have indicated that after the novelty effects wears off, much of the motivating power of the computer is lost. Others suggest, however, that quality drill and practice software can hold students attention much longer than traditional methods.

Several computer drill and practice programs include factors intended to be highly motivational to students. *Math Blasters*, for example, uses a video game format to teach mathematics facts. *Work Munches* is another drill and practice program that uses a game format for added motivation.

Given the advantages of using the computer for drill and practice and the fact that the use of such software may free up time the teacher would otherwise spend preparing and grading these activities, it does appear that there is a place of quality drill and practice software in education.

**Problem Solving Software**

Problem solving software, like simulation software, uses computer capabilities to enhance the teaching and learning of higher order problem solving strategies. Most
problems solving software is similar to simulation software in that students are placed in situations where they can manipulate variables and then receive feedback on the results of these manipulations. Simulation, however, are attempts to model real life situations and objects, whereas problem solving software is a more general category that includes all software designed for teaching problem solving strategies.

A second example of problem solving software is “The Incredible Laboratory” by Sunburst. In this program, users are asked to discover the ingredients necessary for creating colorful and unusual monsters. This program helps students learn to use trial and error in problem solving and to learn effective note taking strategies. Like the King’s Rule, The Incredible Laboratory has several levels of difficulty.

Educators are demonstrating an increased interest in using the capabilities of the computer to allow students to test hypotheses in problem solving situations. Many teachers use these packages with students working in pairs or small groups. Almost all problem-solving software allows the student more freedom to explore than do drill and practice and tutorial programs. Increased popularity of this approach can be documented by scanning software publishing house catalogs that now generally contain an entire section on problem solving in addition to problem solving packages in sections for specific subject areas.

*Computer as Tutor, Tool and Tutee*

One of the best-known systems of computer used in education was proposed by Taylor (1980). Taylor pointed out that the computer can be used as a tutor, as a tool and also as a tutee (3 Ts’).
Computer tutorials, as the name implies, are designed to act as tutors or teachers for students. Concepts are presented and students are given an opportunity to interact with these concepts, much as they would with a teacher.

Like drill and practice programs, computer tutorials vary tremendously in quality. Many early tutorials available on the computer were simple and unimaginative in design. Some simply presented information on the computer screen and occasionally questioned the student about the information. This type of tutorial was termed an “electronic page turner” because the computer was used to present information in a sequential, linear fashion, much as the material would be presented in a book. Most students who have used this type of computer tutorial will testify that such an approach can quickly become boring and tedious. Using the computer to “turn page” as students read through volumes of material is clearly not a good use of the technology. There are, however, techniques that make good use of the power of the technology in producing effective computer tutorials.

Alphabetic Keyboarding, a program published by South Western Publishing Company, USA is an example of a good tutorial program. This program presents information to the student and then gives the student an opportunity to practice using that information. The practice is guided, and the feedback is immediate. Some elementary and middle schools are using this program or similar keyboarding programs as a major portion of the keyboarding curriculum.
Advantages of Computerized Tutorial Programs

Properly designed tutorial programs can offer some real advantages to both teachers and students. Currently, computer tutorial systems cannot reproduce the flexibility and personal knowledge of an individual teacher interacting with a student. On the other hand, they do offer advantages over a single teacher attempting to present material to 30 students at once or over a traditional textbook or programmed text approach. In evaluating tutorials, users should always ask, “What does the tutorial offer that I couldn’t obtain through a more traditional method of presenting information?”

i. Interaction

A well designed computer tutorial should offer opportunities for the student to interact with the material being presented. Throughout the tutorial, the student should have the opportunity to actively participate in the learning experience. This participation must involve more than having the learner answer a series of multiple choice or fill in questions at the end of sections in the tutorial. Students must have a chance to practice new ideas, ask questions, the hypotheses, and check their learning. One of the distinct advantages of using the computer as tutor is that the student can become a more active participant in the learning process.

ii. Individualization

A good tutorial program can adjust the pace of presentation to the needs of each student, a difficult if not impossible task for a single teacher. Using branching
and interactive techniques, the tutorial can provide additional instruction for students who need it and also let faster students move through material rapidly. One important issue for educators interested in the use of tutorials and the information of individualized techniques in these tutorials is the issue of student control versus computer control. In some tutorials, student control the pace and difficulty of the lesson, while in others, the computer uses complex rules to determine what the student will do next. Research in this area has indicated that computer control techniques tend to work better for student learning that student control techniques. However, students apparently can be taught to monitor and control their own learning before the use of student controlled tutorials, and these techniques increase the effectiveness of student controlled programs.

Recent attempts to individualize computer tutorials have included intelligent tutoring systems, that is, tutoring systems based on the principles of artificial intelligence. These ICAI programs contain knowledge of the expert, knowledge about the student, and rules that either explain or reduce the difference between the expert and students models. Thus, an intelligent system contains some type of “production rules” so it can produce strategies on its own. In such a system, the student model usually contains knowledge of student errors. Once the student model has been created and all errors identified, the teaching module can either diagnose students errors, coach the student, or provide a type of “guided discovery” experience for the student. In a review of research on ICAI programs, Dede (1986) states the following:

Educational devices incorporating artificial intelligence (AI) would “understand” what, whom and how they were teaching and could therefore tailor
content and method to the needs of an individual learner without being limited to a repertoire of specified responses (as are conventional computer assisted instruction systems) (p.329).

Although production of ICAI type tutoring systems is currently difficult, time consuming and expensive, these systems are leading educators into some fundamental areas of educational investigation. Identifying student errors and misconceptions and discovering rules and strategies to respond to these misconceptions should add to knowledge about the teaching and learning process and should help with education both on and off the computer.

iii. Efficiency

Almost every classroom teacher has been faced with students who need or want individual instruction. One common reason for this need is student absence. The question, “Did I miss anything?” is universally joked about among teachers, but at the same time, most teachers feel a real need to “re-teach” students who have missed a lesson. Teachers also find the need to “re-teach” slower students. For most teachers, however, time constraints make re-teaching a lesson almost impossible. Computer tutorials are an excellent resource in these situations. For some students, the tutorial might provide a second approach for material they have been taught once, while for others, it can make up for the missed classroom presentation. In both cases, the tutorial can save the teachers’ valuable time.
Although both drill and practice and tutorial computer programs provide some unique capabilities for educators, both types are often classified as applications that use the computer to do what has already been done without it. Maddux (1984) defines type I (using the computer to teach in traditional ways) and type II (using the computer to expand both method and content) uses of the computer. Maddux suggests that much of the early work with computers in schools can be characterized as type I uses of the technology, that is, using the technology to do in a slightly different way what we are already doing in classrooms. Whereas the majority of drill-and-practice and tutorial programs are examples of type I uses of the computer, the following categories of computer can often be classified as type II uses of the machine.

\[ b. \quad \textit{Computer as Tool} \]

Tool software is the category of educational computer software currently receiving the most attention from educators and is an area of emphasis in this text. Tool software is computer software used as a tool to enhance the teaching and learning of almost all subjects taught in schools. Word processors, data base managers, spreadsheets, hypermedia, graphics programs, and statistical analysis packages are all examples of tool software programs currently used in schools. These types of packages are referred to as tools, because like pencils, paper, rulers, typewriters, and calculators, they help students and teachers accomplish tasks but do not specify the content of these tasks. For example, an elementary school teacher might turn to a data base management system as a tool for the teaching and learning
of a mathematics unit on “equations”. The teacher could have students determine what types of information they would like to collect about equations and then assign each student a type of equation to examine. Students could enter the information they collected into a record, and the class would then have a database with information on different types of equations. Students would determine the template, or format, for the records. A record might include some of the following categories: Types of Equations; numbers of degrees; numbers of variables; examples:

The students could then test hypotheses about equations by asking questions and then searching and sorting the “homemade” database in different ways. Questions, like “What are some characteristics of different types of equations?” could be easily studied by searching for all the records on different types of equations. In this type of exercise, students do not merely memorize information an “equation”, instead, they organize, manipulate, and use this information.

The role of the computer in this type of exercise is clearly that of a content independent tool to expand intellectual capabilities. The concept of a tool is certainly not new to teachers and learners. Throughout the industrial revolution, increasingly sophisticated tools were used to extend human powers. As Bork (1985) indicates, “Just as we can speak of mechanical tools as extenders of human physical powers, we can also speak of intellectual tools as extenders of the human intellect. These tools expand the power of our minds” (p.43).

Tool software can take a variety of forms, and it appears to be appropriate for all ages. Kid Pix is a popular computer tool designed for young children. Kid Pix enable s children to combine prepared graphics and their own original graphics and
text in creating their own projects. The package contains motivating tools and prepared graphics that open numerous possibilities for creative young minds. Adults also have reported being intrigued by the possibilities contained in the Kid Pix package, which is available on both Macintosh and IBM computers.

Advantages of Tool Software

As educators strive to discover the most appropriate uses of the computer in the schools, they are discovering many advantages to emphasizing tools software. These advantages include the following:

- Tool software teaches students to manage information
- Students learn how to use tool software
- Tool software is cost effective
- Tool software emphasizes active student involvement
- Tool software gives freedom to the individual teacher

c. Computer as Tutee

With the computer as tutee, the traditional role of the computer in education is reversed. Instead of the computer presenting information to the student, student is now teaching the computer. To teach the computer, the student must learn a language the computer understands and thus must work with a programming language. Taylor argues that “the computer makes a good Tutee because of its dumbness, its patience,
its rigidity and its capacity of being initialized and started over from scratch” (1980, p.4). He suggest that students can teach the computer to be a tutor or a tool, and:

Learners gain new insights into their own thinking through learning to program, and teachers have their understanding of education enriched and broadened as they see how their students can benefit from treating the computer as Tutee. As a result, extended use of the computer as Tutee can shift focus of education in the classroom from end product to process, from acquiring facts to manipulating and understanding them. (Taylor, 1980, p.4)

**Computer Simulations**

A simulation is a representation or model of an event, an object, or a phenomenon. A simulation existed as educational tools long before computers were available in classrooms, the computer has greatly increased the practicality of using simulations in education.

Simulations can be powerful tools for educators. The main advantage of using simulations is that they give the student the power to manipulate various aspects of the model. Students become an active part of the educational environment and can usually see the immediate results of the decisions they make in this environment. In a sense, students are given the power to “play” with a model of the subject being studied and to experience the effects of changing different variables in the model.

Because simulations give students an opportunity to apply their learning to a “real life” situation, these programs tend to address higher order educational
objectives. Usually, a simulation will required the students to perform application, analysis and synthesis level activities.

Lemonade Stand, a simple simulation produced by Apple Computer in 1979, provides a good historical example of some of the characteristics and value of this approach. Lemonade Stand simulates a small business situation in which students make decision about several variables in the business and then receive feedback on the results of these decisions. When using the program, students are told how much money they have and are also given a weather report. Students then decide how many glasses of lemonade to make, how much to charge, and how many advertising signs (which cost money) to make. Students may work through the simulation by themselves or in competition with another student. Students make decisions for particular days and receive feedback on how much profit or loss they achieved that day.

Research on the effectiveness of computer simulations on student learning has produced mixed results. Some researchers indicate that it is difficult to show that simulation increases students learning. Others will argue that traditional learning outcome measures (student achievement tests) focus on low level, knowledge type outcomes and do not adequately measure the higher-level skills students may acquire through simulation experiences. In any case, if simulations are to be used effectively in classroom situations, objectives for the use of these programs must be clearly defined and instruments must be created to measure student success in attaining these objectives.
Taxonomy of Educational Uses of the Computer

A very useful classification system of educational uses of computers has been developed by Thomas and Boysen (1984). They concerned that the traditional method of classifying by the type of software is of no use to the teacher attempting to integrate the computer into the classroom. Knowing that a program is simulation or a tutorial does not help the teacher who wants to know where and how to use the program in instruction. To address this problem, Thomas and Boysen suggest taxonomy of computers use where the classifying variable is the state of the learner with respect to the material. The major value of this is that it gives the teacher direction about where and how to use the computer in instruction. One interesting sidelight of this system is that the same program might be classified in different areas, depending on how the teacher uses the program in instruction.

Experiencing

At this "lowest" level for the Thomas Boysen taxonomy, the learner has not yet received formal instruction and computer programs and use to set the stage of later learning. Used before instruction programs may provide experiences or models for later instruction. For example the Lemonade Stand program might be sued as an experiencing program before a formal unit on mathematics. Some of the basic concepts presented intuitively in the simulation would be use as common experiences and use as points of reference in formal instruction.
Informing

At this level, the students are ready for formal instruction, and the computer is used to deliver the information. Programs use at this level will frequently be chosen from the tutorial software.

Reinforcing

Reinforcing programs are used after formal instruction to strengthen specific learning outcomes. Drill and practice programs will frequently be used at this point in instruction, but sometimes a tutorial will present information in an interesting alternative fashion providing a useful made of reinforcing.

Integrating

Integrating programs let the student apply previous learning to new situations as well as associate previously unconnected ideas. Here students are frequently asked to manipulate and apply information beyond the classroom presentation. Simulations might be especially appropriate for learners at this level.

Utilizing

Here the computer is used as a tool in the manipulation of the subject matter. At his stage, the student might use a data based to research questions about a particular concept of mathematics or a statistical program to analyze research data.
In terms of unique contributions that the computer can make to education experiencing integrating and utilizing programs appear to show the most promise. Before the availability of the computer, providing students quality experiences in these three area was a problem for teachers. Simulations, problem solving software and tool software all provide exciting possibilities for enriching students experiences before formal instruction and or integrating and using information after instruction.

**Problems with Using Computer Effectively in the Classroom**

The capabilities of the computer offer exciting possibilities for educators to expand and enhance the curriculum. With the arrival of new technology, some problems and challenges that may keep educators from using the full potential of the computer are described in this section.

**Inadequate Teacher Training**

Using the computer for drill and practice of tutorial applications required little additional training of the classroom teacher. Making use however, of computer software that required more student involvement (simulations, tools, programming) requires more teacher involvements. These higher level applications of the technology define and expand the types of computer experiences necessary for teachers to evaluate and use the most power full classroom compute applications.
Teachers cannot use computer tools in the teaching until they have had an opportunity to use these tools themselves. Unfortunately, most teachers have not had such an opportunity. Certainly, teachers who have never used a data base system cannot be expected to devise classroom applications of such a system, and teachers who have never used a word processor cannot be expected to create writing activities appropriate for word processing.

Unfortunately, learning to use tool applications of the computer is a time and energy-consuming project. It is clear that teachers are not going to learn these skills in a few two hour workshops and school administration must be more willing to furnish funds for organizing workshops to help their teachers learn and experience the power of the technology.

Some teacher works extensively with computer tools (usually self learning), and many of them are creating interesting applications of the classroom. Most teachers, however, still have not had the opportunity to attend in-depth workshops on computer applications and thus have problems understanding and devising type II computer applications (using the computer to expand both method and content) for their students.

In Pakistani context, the deficiency of training and use of computer tools is mostly compensated in workshops and during refresher courses. In addition, most of the computer teachers are employed on the basis of their pre-academics and professional qualification. Therefore, they are in better situation to handle the computer science course.
Lack of integration into the Curriculum

Many teachers and schools are currently “getting students on the computers,” yet the students are having isolated, disconnected encounters with the technology. Some schools have even mandated that students will be on the machines for “30 minutes a week” with little direction as to what students will do during that time. In one school, students spend their 30 minutes a week choosing a disk, running the program, and then choosing another disk and repeating the process. There is no plan, no student accountability, and no connection with any other learning activities going on in the regular classroom. Although computer related technologies are not directly integrated in Pakistani curriculum but still there is a room for use of these technologies in class rooms depending on caliber of teachers and the time available to them.

Lack of teacher training can be cited as one explanation of the lack of integration of the computer into the curriculum. A second reason may be the tendency to place all the computers in a school in a laboratory and hire a computer teacher to run the laboratory. Sometimes, the computer laboratory model encourages teachers to view the computer as something to be taught rather than as a tool to enhance teaching. With this model, the classroom teacher may send the students off to the specialist to “learn computers” just as he/she might send the students to the PTI to learn to play the cricket. In Pakistan, most of the schools are being equipped with computer laboratories and there is a lot of encouragement for using these facilities.
One computer teacher has devised an interesting solution to this dilemma. Although he teaches his computer classes in a middle school as a separate subject, he uses the class to help other faculty in the school become more involved with computers. For the final project for the class, each student is asked to find a teacher in the school and interview the teacher about what type of computer application the teacher would like for his/her teaching. The student then works with the teacher in designing or locating and implementing the application.

**Dynamic Nature of Computing**

Given the basic conservative nature of the schools and the perpetual problems with obtaining adequate funds, the fast paced, dynamic nature of the computer industry presents some real problems. Just as schools are outfitted with computers, the machines become obsolete, and newer, faster, more powerful models are available that will run "the newest software." Needless to say, most school systems are not financially equipped to replace computer equipment every two or three years, as the rate of development of the industry would dictate.

In addition to the problems of paying for the new equipment, the new equipment and new software compound is required for teacher training. Obviously the new equipment required new training for a staff who may feel that they have just began to master the older equipment. The situation becomes even alarming when limited resources are available to the Pakistani schools. The dynamic nature of computer is thus needs to be balanced with country resources.
Although perhaps appropriate for using some types of tool software, the argument that schools do not need the new sets versions of software does not cover all potential computer use in schools. New developments in computer education emphasize the creation of powerful simulated environments where students can make decisions and apply information. Most of these environments require software beyond what is available of most students in most schools. Becker (1991a) cited lack of up to date hardware as one of the three major difficulties in school computer use. Clearly, the problem cannot be ignored.

Differentiation among the terms CAI, CBI, OR CBL.

The terms computer assisted instruction (CAI), Compute based instruction (CBI), and computer based learning (CBL) are all used frequently to describe computer applications in education. Although the term CAI sometimes refers broadly to all education software, it usually means a programmed learning approach in which specific educational objectives are achieved through step-by-step instruction. The term instruction in CAI is usually interpreted as a view of the computer as delivering information to the student. Thus, for many, the term CAI refers to drill and practice and tutorial types of computer programs.

A term, CBI, is also use frequently, but again, the term instruction might imply only educational uses of the computer where the computer is delivering information to the student and does not include the tool usages of the machine. When this term is used, it refers to use of the computer to deliver information to the student.
The term CBL is gaining popularity to describe all students learning related to the computer. Some consider this term more generally because the term learning more naturally encompasses situations where the computer is used as in educational tool but is not delivering information or instructing the student. The term CBL is therefore used as the umbrella term for all educational uses of the computer.

**Computer Based Instruction (CBI)**

**Design of CBI**

The programmed instruction research, and more recent research on microcomputer use, have produced several generalizable conclusions about how CBI should be designed. The Design of CBI is described in brief.

**Knowledge of Correct Results**

Knowledge of correct results (KCR) is one technique identified by both research and theory as important. Students should have correct responses reinforced in some positive manner. It is also effective to give students clues when incorrect answers are given. In a lesson on vocabulary, students who spell a name incorrectly but close to the correct spelling should be told they have made a spelling error rather than that their answer is incorrect. Clues and prompts should positively reinforce
what was right about the response and should give students directions about how to correct what was wrong with the answer. In a drill or tutorial lesson a rule of thumb is to allow two or three incorrect answers before students are given the correct response.

*Feedback*

Students should be given information about their progress through a lesson, both during the lesson and at the end of the lesson. Games are popular with students partly because they usually give students immediate feedback. This not only reinforces the correct response, it also makes the activity more interesting and motivating.

When a lesson is concluded, students should be given feedback on their progress. While a simple score, such as 8 problems solved out of 10, is feedback a more complete diagnosis of student progress is much more effective. Recommendations for additional instructional activities are also appropriate. For example, a computer lesson on balancing chemical equations could give the student information on how many problems were solved correctly, on what kinds of problems the students seemed to do well, and to what kinds or topics the student did not do well. Additionally, the lesson might recommend that the student brush up on the periodic chart by taking a drill lesson on the symbols for the element before attempting more equation balancing. In other words, the closer the feedback from a computer lesson matches what a live tutor would say to a student, the more effective the feedback will be.
Feedback in an interactive multimedia environment would be different. Certainly, a test could be given to quantitatively assess students' learning. Also, an assessment of how the students used the lesson might provide further feedback. Information about how many branches were used, or which nodes in the lesson were visited, might help the students analyze their learning. Probably new types of assessment and feedback will be necessary for new types of computer-based instruction.

Branching

Branching the route a student takes through a lesson, is directly related to KCR and feedback. Usually, branches that students take through a lesson depend on their responses to questions. For example a student who misses a self test question on the solution of quadratic equations might be branched to review section of the lesson that deals with the system of linear equations and their solution.

Another characteristic of effective CBI is assessment. Students should be assessed during and at the conclusion of lessons. Obviously, assessment is closely related to both KCR and feedback. Testing gives the students information about how well the lesson is being completed.

Less obtrusive, or obvious, assessment also can be given. Student response times can be monitored to determine if information is clearly understood or if students must figure things out before answering. For example, in a drill, the amount
of time an elementary student takes to complete short division problems is probably related to ability. Students who take longer probably need more practice.

Computer based lessons also can diagnose a student during a lesson, much as a competent teacher "gets a feeling" for how well a student is doing. Obviously, this kind of assessment is much more difficult, but as CBI continues to improve, it will become easier. Most important, the research indicates that this kind of "intuitive" assessment is important.

Advance Organizers

Lessons that indicate to students where they are going and what is expected of them generally produce higher achievement levels than lessons without this kind of simple advance organizer. Behaviorally stated objectives that are shown to the student are the beginning of a lesson act as organizers and have been found to enhance student achievement.

More subtle advance organizers that preview subsequent information and prepare the learner for what is expected to them can, and should be used throughout lessons. Just as a good teacher previews the next days lesson, an effective computer lesson can indicate the relationship between what is learned first (e.g., the restriction of access to raw materials because of naval blockades during wartime).
**Prompts**

Effective teachers prompt or give clues to students to help them reach correct conclusions. Good CBI should do the same. Prompt can be as simple as “You’re close, try spelling the name of the state differently, “to something as sophisticated as “think about the problem differently. What could you say to be more descriptive instead of 80 feet high? Is there any structure in your home town that is about that tall?” Prompts guide student responses. They help students understand and are an important characteristic of effective teaching. Prompts can also be used to provide structure to an interactive multimedia lesson and help students stay on task.

**Pacing**

There was a time when variable pacing was considered the major contribution to teaching that individualized instruction had to offer. Advocates of mastery learning principles have demonstrated something called the “90/90 rule.” This rule states that 90% of students can learn 90% of what is important about any topic, given adequate time. Interestingly enough, research has supported this idea, and one of the major forces behind the push to individualize instruction is the belief that one important reason some children achieve more that others is that they learn faster, not more. The idea of “fastness of learning” was considered an inadequate reason for labeling some as less intelligent.

One important characteristic of CBI is that it tends to be individualized. Students proceed through learning activities by themselves, at their own pace. In
classrooms with one teacher and 30 students, a uniform pace must be set. This pace is too fast for some and too slow for others and advocates of mastery learning principles would claim this is largely why some children achieve better than others. Computer based individualized instruction eliminates this problem. Certainly, learners do not have infinite time. Well designed lessons assist the student to use their time well and wisely.

Screen Design

As microcomputers have proliferated, so has concern over how information is presented on the multitude of screens in use. Recently, considerable research on screen design has been reported, and more is under way. This is an area of continuing interest to computer educators. As early as 1973, James Martin wrote, “As yet, no acknowledged sense of style has developed for Computer Assisted Instruction (CAI)... In the meantime, however, some singularly unstylish CAI programs are being written” (in Heines, 1984, p.130).

Screen style is still an issue. Resolution of the screen should be the first style consideration when CBI is designed. The screens used with some microcomputers have very low resolution, meaning that they do not produce high quality images. In general, anything written or drawn on computer screen will be of lower quality, or resolution, than it would be if it were written on paper. When screens are designed, and when teachers evaluate a lesson's screen, three areas should be considered: the kind of information presented, the screen components, and the readability of the information shown.
Also, the use of visual metaphors has been found to be useful. Visual metaphors are as simple as the icons used to depict files, folders, and trash. They can be as sophisticated as visual mnemonics that help learners remember sophisticated ideas. The “It is not how hard you work, it is how much you get done” visual of the farmer taking pigs to market.

*Screen Information*

Words, graphics, and space are the three kinds of “information” on a computer screen. Generally, all are used in effective screen design. Graphics should be designed according to the level of realism required by the sophistication of the students who will use the lesson. Dale’s Cone of Experience (Dale, 1946) is a guide here. Students who have not had sufficient realistic experiences with the content of the symbol will not understand abstract symbols. In other words, line drawings, outlines, and diagrams may not be effective. The kinds of visual information presented by a computer lesson must be evaluated in terms of not only the lesson’s content but also the learners experience level. Other information presented on the screen must be evaluated in the same manner.

Usually, it is best if one idea or topic is presented on one screen at a time. Simple is usually better then a complex. Multiple ideas shown on one screen tend to confuse the student. On the other hand, if topics are closely related, it may be necessary to retain portions of one screen when a new topic is presented. A compromise would be to give the student the option of reviewing screens shown.
previously. When graphics or drawings are shown to students they tend to load at them in a clockwise sequence. Usually, the eye first looks at the upper left quadrant of the screen tend moves clockwise around the screen. Prompts such as arrows or directions can be used to reinforce or alter this natural viewing pattern.

*Screen Components*

The way the computer screen is organized should give the student a feeling of control. No learners enjoy being placed in a situation where they have no say in what is happening. First, the screen should provide orientation information to the student. This might include statements about where the student is in the sequence of the lesson, analogous to page numbering in a book. Some call this information to the lesson's "cognitive map." Because it is hypothetically easy to get lost in a lesson (lost in hyperspace), especially a hypermedia lesson, it is important that students know where they are. A lesson's cognitive map gives such a orientation information.

Students also need to know how to move through the lesson. A "navigation system" can help. Simple page turning or screen changing is a kind of navigation system, but more sophisticated lesson have easy to use ways of "jumping around" in a lesson, such as to the beginning of a section, or back to the lessons start. Effective CBI lesson have cognitive maps and navigation systems. Lesson section titles can be used, as can visual symbols that indicate where the student is within the lesson.

Directions should be clearly given to students about what they are expected to do. These directions can be as simple as "Read this and press Return" or as sophisticate as "Solve this problem, and type in your answer using this form,"
directions for how a student can return to a major subsection of a lesson. "Safe havens" for learners can be the home page, a table of contents page, or a section start up page. Effective lessons even use bookmarks within computer based instruction so the learner can easily return to the spot they left off.

Readability

Because the resolution of a computer screen is generally lower than a for a page of a book, extreme care must be taken to ensure that what is written can be read. First, writing should be simple. Long, complex prose is not meant to be read from a computer screen. Next, upper and lower case lettering should be used because it is easier to read. Third, justified right margins should be avoided. Ragged right margins show up better on more computer screens. Fourth, shorter rather than longer lines are
best. Eighty column text displays should be avoided, if possible. Forty columns of text is the standard. Last, one letter size should be used for all text.

**Characteristics of CBI**

The method of teaching with computers is directly related to student achievement. Computers, like any tool, can be used weather correctly or incorrectly. Teachers should attempt to maximize the positive effect computers can have and minimize potential negative influences. For this, the following characteristics of CBI may be considered:

*Individualization*

CBI is an individualized approach to teaching. Students should be allowed to work at their own rate. Several researchers have reported that two students can work together on a lesson with no apparent loss of effectiveness. However, when more than two students work on one computer at a time, some students learning likely will be adversely affected (Klinkefus, 1988), unless the lesson is designed to be a collaborative one. Increasingly, individualized instruction means that the computer does not always deliver instruction while the learner receives it. Rather, students interact with a computer controlled learning environment and construct meaning while participating in learning activities.
Learner Control

When teachers direct instructional activities, they control pace and direction. When computers are used to deliver instruction, the focus of control changes. Originally, most CBI allowed the student considerable flexibility in controlling the pace and route of the lesson. Recent research demonstrates that this may not always be a good review when review is needed, might not follow remediation directions when they are suggested, or might not read all information presented when they have complete control over the program. Increasingly, CBI is being designed so the computer has some ability to regulate a student’s progress.

Attitude Change

Lessons that present new information require both physical and intellectual involvement and present relevant information are most likely to be favorably received and to produce positive attitudes. These positive attitudes would be directed towards both the contents of the lesson and the use of the computer. In other words, it is possible to design CBI so that student’s attitudes can be changed both toward the topic being taught and toward the importance of CBI.

Computer Anxiety

Computer anxiety, the fear felt by people when using computers, or when computer use is anticipated, is a documented problem for certain individuals. A
significant proportion of any group of computer users will be considerably more anxious than others in the same group and this anxiety has been shown to be related to problems these people have when they use computers. There is also growing evidence that there is a gender difference related to computer anxiety. Girls and women tend to be more anxious than boys and men. Researchers have indicated that students should be diagnosed for anxiety, and those students with high levels of computer anxiety should be given individual attention to reduce their apprehension. Currently, most evidence indicates that individual attention from a trained and sensitive tutor is the best way to reduce a student’s anxiety level. Merely requiring anxious students to work on the computer to overcome their fears will not reduce anxiety. As a matter of fact, this kind of “throwing them in the deep end” remediation produces more anxiety and is likely to produce computer hatred (Maurer & Simonson, 1994).

*Computer Laboratories*

Accessibility is strongly related to use. Teachers and students who have easy access to computers are most likely to use them. The more roadblocks that are placed between the user and the computer, the less likely is that computers will be used. If use is to be promoted, then computers should be distributed throughout the school in classrooms and small labs. Centralizing computers in laboratories, or media centers, may have many management advantages, but it may reduce use.
Because of the relative newness of CBI much of the information about use is not adequately documented. Anecdotal information abounds, but scientific evidence is somewhat scarce. Educators should proceed cautiously when making decisions about how CBI is implemented. Local field-testing of procedures is a must.

Educators should not forget, however, that techniques proposed by theory, and supported by research, from the foundation for effective CBI will be presented. Teaching is a profession. Decisions should be “founded upon a body of intellectual theory and research.... The practice of a profession cannot be disjointed from its theoretical understandings” (Finn, 1953, p.8)

**Computer Based Learning (CBL)**

As the position of the computer in education continues to mature, the computer is increasingly being coupled with other technologies to create quality learning experiences for students. Used with a telephone through a modem, the computer can be used as a tool to enable communication between classrooms around the country. Coupled with video disk player, the computer can be used to create tutorial or simulation programs with video input. Coupled with a speech synthesizer, the computer can read students writing back to them. Thus, CBL is not limited to students, computers and software but can also include and encompass various combinations of the computer with other advanced technologies to create learning experiences for students. The term computer related technologies is gaining popularity as a way of describing the hardware used in conjunction with computers.
The Role of Teachers in CBL

Using Computer-Based Learning approach in the classroom, teachers should be familiar with different roles. Hannafin and Savenye (1993) and Cheung (1995) pointed out that when Information technology is used in classrooms, teachers act as managers, organizers, coaches, guides, initiators, and facilitators. The role of teacher in this context is described briefly.

Teacher as Organizer

When teachers take the role as a manager or an organizer, they manage the learning environment for the students (Cheung, 1995). Cheung summarized teachers' role as a manager or organizer in the following:

“Teachers should act as the manager to manage the learning environment for the learners. Their duty includes selecting and organizing the hardware and software. ... When teachers take the new role, they may need to learn and use new classroom management techniques for using the hypermedia software packages and the on-line program in classrooms... Teachers need to set up discipline rules and computer facilities to avoid the classroom management problems (Cheung, 1995, p.190)”
Teacher as Initiator and Facilitator

When teachers take the role of initiator, they introduce the use of Internet to the students. They explain the potential and the benefits of using internet in their learning environment to the students. When teachers take the role of facilitator, they provide encouragement and stimulate students to use the on-line programs.

Teacher as Coach and Guide

When teachers act as a coach or a guide, they should show the students how and when to use on-line programs. Guidance might include the procedure, strategies, and skills of using Internet during their learning process. Teachers should provide exercise and feedbacks to the students during the use of commercial packages and while students are developing their own Internet.

Teachers as Software Evaluator

Teachers should evaluate commercial hypermedia software packages for students to use (Cheung, 1995), and evaluate the type of authoring tool used by their students. Teachers may also evaluate students' on-line projects (Dipinto & Tuner, 1995).

Researches on Use of Information and Communication Technology in Teaching

This research studies review included use of computers in teaching by first defining some terms used in information and communication technology and then examining the influence of computer technologies on mathematics teaching. Because
the teaching approaches used in the study included various multi-media elements, the history of media comparisons studies are therefore reviewed, including meta-analyses of the effects of computer-based learning and the limitations of these studies. Learning theories then considered for re-framing the theoretical foundation in future research on computer-based instruction. Learning styles also explored as they influence success in learning. In particular, the research on learner control is examined because of its presence in CBL Approach. Finally, this review explored design strategies applicable to student learning in computer-based learning systems and Web-based hypermedia environments.

The terms describing instructional technologies reflect a variety of applications that have evolved in the last two decades. Computer-assisted instruction (CAI), computer-assisted-learning (CAL) and computer-based-instruction (CBI) have been associated with earlier forms of technology often associated with self-paced instruction. A more popular term, currently used to include a variety of technology enhanced learning environments is computer-based-learning (CBL) (Thompson, et, al., 1996). The On-line teaching can also be referred to as a form of computer-based-learning as the locus of activity shifts to the students’ role in learning.

Many of the recent terms describing computer-based-learning reflect the multiple venues of learning made possible by the Internet, such as asynchronous-learning Networks (ALN), Web-based learning (WBL), human-computer interaction (HCI), multiple user domain (MUD). More importantly, the Computer-based learning is used in this review of the research to cover a wide variety of computer based
learning systems that offer a high degree of interactivity, self-pacing, autonomy, and learner control for the students.

**Media Comparison Studies**

Research on computers in education began in earnest in the 1960s. In a book by Skinner in 1965, he stated that using computers to teach could build "confidence in education" (p.19). A substantial body of studies has attempted to measure the effects of various media on learning but have produced inconclusive results since 1960s. Richard Clark points out "media do not influence learning under any conditions" (1983). The empirical method of research pivots on the importance of the testing hypotheses under the rigor of the scientific method. A scientific statement must be able to be falsified, explanatory, predictive, productive, and persuasive to qualify as a true operational hypothesis (Unsworth, 1997). When put to the test, most educational research comparing media has failed to identify significant outcomes in learning that can be attributed to media or modes of delivery.

When media comparison studies employ rigorous methodology, the results have often been "no significant difference" in learning outcomes regardless of the media (Russell, 1999). Citing studies beginning in radio from 1928, television in the 1940s to 1960s, video in the 1970s to 1980s, computer-mediated learning in the 1980s, and Computer-based learning in the 1990s, most of these studies remain inconclusive (Russell, 1999). Russell uses these studies to support a theory of equivalence in distance education studies. Alternative deliveries such as computer-
based learning are often used for distance education programs, where the students are physically separated from the instructor. If the delivery of such programs results in similar learning outcomes, comparative studies could be used for summative data to establish the equivalency of a particular form of delivery. It should be noted, however, that the real variable being compared is the content and instructional design, rather than the technology or mode of delivery.

A recent report, commissioned by the American Federation of Teachers and the National Education Association, reached far different conclusions than Russell on the research in computer-based learning in distance learning (Phipps & Merisotis, 1999). Similar to Clarke's view, this report took a critical view of the literature cited in 40 original studies on distance education. They point out the lack of rigor in much research, which "renders many of the findings inconclusive," (Phipps & Merisotis, 1999). Two of the shortcomings noted were an inability to control extraneous variables needed to show cause and effect and a lack of randomly selected samples. Another problem cited was the validity and reliability of instruments used to measure student achievement (Phipps & Merisotis, 1999).

Although a lack of rigor in distance education research is a serious shortcoming in most of these studies, the conditions needed for experimental studies may be unrealistic for much research and evaluation conducted by educators in real classroom environments. A hidden fear surfaced in their concern that "technology cannot replace the human factor in higher education" (Phipps & Merisotis, 1999). Because multimedia does not take the place of the instructor, a more rational position gleaned from the research could be that "learning is more correctly attributable to
well-orchestrated design strategies than to the inherent superiority of various media” (Hannafin & Hooper, 1993). The purpose of educational research has shifted from comparing media to exploring strategies for the best use of educational technologies in student learning, including the human element of interaction among students and instructors and with each other, as well as the use of effective instructional strategies through computer-based learning.

One significant empirical study on student achievement using computer-assisted technology was conducted by the state of West Virginia in a collaborative and well-documented partnership with the Milken Family Foundation. This study was conducted over eight years and represented a statewide technology initiative. Data were collected from 950 fifth graders who were randomly selected from 18 elementary schools Solomon, et al., 1998). Students were normed on the Stanford 9 achievement tests over four years. It should be noted that there were other mitigating factors that could account for gains in achievement such as: renovation of school buildings, new instructional methods, and increased teacher pay. Nevertheless, the 11% gains in achievement may imply that technology can have a positive effect on learning, when implemented on large scale and with a concerted effort. These gains may also reflect instructional design strategies and methodology implemented by individual instructors, as well as the technology or media use to deliver the instruction.
Another approach to research in computer-based learning has been the use of meta-analyses to review a large number of studies that have compared computer-based learning with traditional methods of delivery. Meta-analyses conducted by Kulik and Kulik (1980, 1984, 1987, 1991) summarized the findings of 248 controlled evaluation studies of technology-mediated learning. In 81% of these studies, students in technology-mediated studies achieved a higher mean examination score than students in traditionally-taught classes. Technologically-mediated instructional settings raised the examination score of the typical student by 0.30 standard deviation (Kulik & Kulik, 1991). They also found that these students required only 70% as much instructional time as students who were taught traditionally. In only 3 of 32 studies did they find traditional instruction to be a more efficient use of time (Kulik & Kulik, 1987). Although Kulik and Kulik reported positive effects of computer-assisted instruction in their meta-analyses of a large body of research, the statistical power of using multiple studies is compromised in the confounding of variables. Computer-based instruction itself represents many different forms as new technologies emerge. These new technologies and media are rarely distinguished from the instructional design and content they deliver as pointed out by Clark.

The wide variety of computer-based technologies cannot be easily generalized into the single variable such as media or computer-based instruction. Considering the changing nature of technology, as well as its multiple applications and uses in instructional programs, meta-analyses face the fundamental problem of isolating the
variable of computer-based technology, which changes significantly over time and is used in an increasing wide variety of applications. In some cases, CBI has been used only for evaluation, while other times it includes instructional activities such as drill and practice. While most of Kulik and Kulik’s meta-analyses used first-generation technology-mediated instructional systems, current multi-media environments may allow for more interactivity. However Clark (1985) found more serious flaws in Kuliks’ meta-analyses.

Clark (1985) examined the confounding of computer-based instruction (CBI) effects in the Kuliks’ meta-analyses demonstrating serious problems in construct validity in CBI studies. When CBI modes are compared with traditional delivery, a confounding of medium and method often occurs. Because instructional methods are imbedded in CBI treatments, traditional treatments need to contain equivalent instructional methods to isolate the effect of CBI (Clark, 1985). Achievement gains found in CBI studies have not separated the media or mode of delivery from the embedded instruction within these media or modes of delivery. According to Clark (1985), gains in achievement are attributable to the instructional method and content rather than the method or mode of delivery. A fundamental problem in meta-analyses as well as most CBI studies is a confusion of two types of technology: design and delivery. Design includes instructional methods and organization of the content that affects learning or achievement, while delivery technology refers to the media or vehicle used to deliver instruction. Based on this distinction between design and delivery, Clark (1983, 1994) asserts that media do not influence learning, but merely provide access. Modes of delivery, including computer-based technology, are “mere
media that may be vehicles of instruction but should not to be confused with instruction itself” (Clark 1994).

The confounding of instruction with delivery is further compounded when the instructor effect is considered. This effect can take two directions. CBI studies that use more than one instructor often fail to control for the differences between individual teachers, including methods and individual styles that may affect student achievement. Even in studies that use the same instructor to deliver both CBI and traditional instructional treatments, instructors may consciously or unconsciously affect learning outcomes, depending on their attitudes regarding CBI technology. Clark (1985) describes the “John Henry” effect when teachers use less robust methods in implementing the CBI treatment. When more robust instruction is used in CBI treatment, the result is an overestimation of the CBI effect on achievement. When teachers resist CBI or feel threatened by it, the effects on achievement may be underestimated (Clark, 1985).

Learning Theories: Reframing CBL Research

Learning theories provide fundamental frameworks for understanding computer-based learning and how knowledge is constructed. The theoretical framework for research in education is grounded in the behaviorist tradition of cause and effect that measures learning as a change in behavior. The psychological behaviorism of B.F. Skinner centers on the interaction of stimulus and response measured in observable behaviors. This emphasis on external behavior produces hard
data for educational research needed to quantify learning into measurable units or outcomes.

Although behaviorism provides a solid empirical foundation for isolating variables and measuring learning gains, it provides a limited understanding of the internal dynamics of learning and the formation of knowledge. Contemporary research and evaluation with emerging technologies is often rooted in cognitive learning theories (Hannifin, et al., 1996). Cognitive learning theories attempt to encompass the internal or cognitive processes that occur within the individual that contribute to learning. Rather than viewing learning in external outcomes based on stimuli and responses, cognitive theory begins within the individual. Central to the cognitive view of learning is the assumption that the individual actively constructs knowledge based on previous knowledge, accretion, and schema creation (Seel & Winn, 1996). Knowledge is constructed as learners actively process information relevant to their experiences, abilities, and motivation. Viewing knowledge as a process of construction shifts the focus of learning to the subject as an active learner, rather than passive recipient. When human learning is viewed as an active process of knowledge construction, it is heavily dependent on the learner's ability to strategically manage and organize all available information resources.

Clark's argument that media have no intrinsic properties to make them instructionally effective is framed within the behaviorist tradition that views learning as presentation of external stimuli and views learning as corresponding and direct response. In this theoretical framework, an instructor is always required to effectively organize and design instruction. Media are mere instruments for the presentation of
stimuli. Contrary to Clark’s theoretical position, Kozma (1991) asserts that media may have unique and important roles to play in learning, as sufficient, if not necessary, conditions for learning. Kozma (1994) also appeals to semiotics and the linguistic role media can play as signs and symbols in communication systems. From a cognitive and semiotic perspective, media may facilitate operations the learner is capable to perform, but more depends on the learner as playing a central role in learning.

While traditional research on learning has focused on the way people change their behavior or ability to do something as a result of an environmental stimulus (media), cognitive conceptions of learning stress that learning is an active, constructive, and goal-directed process. “Cognitive media research assumes that the individual is mentally active, organizing and processing information from the environment rather than simply responding directly to external stimuli” (Seel & Winn, 1996, pp. 293-322). Closely related to the cognitive theory that learners construct much of their own learning experiences is an emerging field of learner control research.

**Learner Control Research**

A central feature of computer-based instruction is the provision of learner control—the ability of learners to make their own decisions regarding some aspect of the "path," "flow," or "events" of instruction (Williams, 1996). One rationale for learner control is to increase learner involvement, mental investment, mindfulness, and activity. However, research has shown the type of control learners should have
varies widely with content as well as the characteristics of the learners themselves in any given situation (Duchastel, 1986). One major advantage of computer-based instruction (CBI) is to provide for different needs and abilities of individual learners. One way of adapting to individual needs is to allow students to exert control over the learning environment. In learner control, students can determine what pace they move through a program, which instructional features they would like to use, the amount of practice and explanations, as well as when to take mastery tests. Although the concept of learner control has long held an intuitive appeal, its potential for improving learning has yet to be established in experimental research. Learner control is based on the assumptions that learners know what is best for them, and are capable of making appropriate choices regarding their own learning (Jonassen, 1996).

Some studies reveal that not all students make appropriate use of educational decisions. Duchastel (1986) cautions that "the sophistication of the learner and the type of objectives pursued, as well as the particular context of the system, will probably impact on the nature and effectiveness of learner control in given situations". Duchastel's caution about the learner control hypothesis is based on its complexity, the diversity of learning itself, the many different learning contexts, and the requirements of individual learners.

Some students may be poor judges of how much instruction they need. With so little support in the literature, Carrier (1984) cautioned against the blanket use of learner control in allowing students to exercise their own judgment about how much instruction they need and in what order. Because of the wide variety of learners and
learning styles, the successful use of learner control may depend upon granting control to certain types of learners and under certain conditions.

Learners differ with respect to how well they perform under learner control conditions. One important factor predicting success in learner control is prior knowledge. Carrier, Davidson, and Williams (1985) found that higher ability students tended to see more optional materials than students of lower ability (Carrier et al., 1985). The researchers noted the importance of persistence as an important factor in this study. Students who were fatigued by the amount of material provided may have given up early in the lesson. Although lower ability students selected less optional material, it was not shown that these students would have profited from an enriched lesson with a high density of information. The researchers concluded that "placing a child in a situation which has a high level of instructionally-relevant content does not insure that he or she will attend to or use this information productively" (Carrier, et al., 1985, pp.49-54). In a later study, Carrier and Williams (1988) found positive effects of learner control for students with high task persistence. This study measured 114 sixth graders of differing levels for task persistence using learner control and program control. Learner control was represented by an options treatment where students were allowed to choose from a variety of elaborative material. This was contrasted by a full treatment, in which all the elaborative material was mandatory and a lean treatment that provided only a core presentation with no elaborative material. Results showed that under both program control treatments, persistence was related to performance; Low and high persistence groups preformed more poorly than did medium persistence groups. Under learner control, however, the highest task
persistence groups performed best (Carrier & Williams, 1988). When the amount of material seen was controlled for, the learner-control group performed better than the program-control groups.

Several cognitive variables mediate the effects of learner control. Hannafin (1984) concluded that more-able students would benefit from learner control options than less-able ones. Consequently, most learner control studies include a measure of general ability. The effectiveness of learner control also can be examined from a meta-cognitive perspective. Tennyson and Park (1984) suggested that the effectiveness of learner choices will depend on the accuracy of a learner's "perceived need" for additional support.

The results of Carrier and Williams' (1988) study provided support for the beneficial effects of choice within an instructional task. The learner-control treatment was superior to the program-control treatments, especially for the moderate groups, which represent the majority of students. Students in this study clearly benefited from the opportunity to exert control over the type and amount of instruction they received (Carrier & Williams, 1988). The psychological reactions to choice/control may play an important role in the effects of learner control strategy that can reinforce persistence with academic success.

Many researchers have failed to provide adequate operational definitions of their learner control treatments, resulting in ambiguous experimental designs (Reeves, 1993). Many studies used quantitative methods when qualitative methods would have been more appropriate. Another problem was the confounding of learner-control or program-control treatments with the amount of instruction students see during the
lesson. Because these students select less instructional material, they receive an incomplete lesson compared with their program-controlled counterparts (Lepper, 1985). Carrier and Williams (1988) experimentally controlled the amount of material seen, and found a positive effect for the amount of material separate from learner control or program control effects. The studies that control for the amount of instruction separately from learner control have been rare, however. Because the studies have been so varied, with unique operations, instruments, designs, and analysis, meta-analyses are especially misleading in learner control research (Reeves, 1993).

There may be several reasons for the mixed achievement results in studies of learner control. Instructional programs using learner control vary widely, as do operational definitions of learner control. In some studies, learners have had the option to add instruction to a relatively lean program that contains only a basic amount of information, thereby lengthening the program and receiving more instruction. In other studies, learner control gives students the option to by-pass instruction in a relatively full program, thereby shortening the program and receiving less instruction. In such cases, learner control does not increase the effectiveness of the full program and may even decrease it. In other learning contexts, learning control conditions have had positive effects on student achievement (Ross, Morrison, & O'Dell, 1989; Gray, 1987; Kinzie et al., 1988).

Some studies have demonstrated positive effects of learner control on achievement. In a study by Ross, Morrison, and O'Dell (1989) undergraduate education majors allowed to select the instructional presentation medium, achieved
higher posttest scores than students who were not allowed this option. Kinzie, et al. (1988) found that students given control over reviewing content scored higher than those not given this option. Gray (1987) reported that college students having control over sequencing content in a sociology class scored higher on a retention measure than students without sequencing control. Some literature suggests students may benefit from controlling elements of their instruction when informed about their own strategies for learning a task (Ross, Morrison, & O'Dell, 1989; Gray, 1987; Kinzie et al. 1988).

A series of studies have investigated the effects of learner control in full and lean instructional programs. Some of these studies indicate that learner control mitigates the achievement advantage that would be expected to favor full program control over the lean program control. Participants given learner control in the full program chose to bypass about 20 percent of the optional elements, while those in the lean programs chose to add 30-40 percent of the optional elements open to them, thus reducing the difference in the amount of instruction that would have been received by the full and lean groups under program control (Hannafin & Sullivan, 1995; Pollock & Sullivan, 1990). Normally learners follow a default version of the program but when students are strongly motivated to do well in a course, they have been found to add 70 percent of the additional options available to them.

Time spent in the program can have positive effects upon achievement. Students need to be given learning strategies to make good choices in exercising learner control. Tennyson (1980) reported that students who received advisement in an instructional program spent more time and chose more options than participants
not given control over the amount and sequence of elements in the program. Schnackenberg, Sullivan, Leader, and Jones (1998) found that college students who used a full version of an instructional program with 242 screens without learner control did not spend significantly more time in the program than participants in the lean program containing only 158 screens. Students tend to compensate for the lesser amount of basic instruction in lean programs by exercising learner control options. Participants in the lean program may have compensated for their fewer screens by spending more time per screen in the program.

Student ability is another factor influencing the effectiveness of learner control within CBL systems. Many studies have show that lower-ability students benefit more from full program control than learner control (Ross & Rakow, 1981; Goetzfried & Hannafin, 1985). Lower-ability students often spend less time on task in a learner control treatment than higher ability participants. Hannafin and Sullivan (1995) found that higher-ability students in a learner controlled treatment chose to add optional elements in 43% of the cases, compared to only 19% of the cases for the lower ability students in the same treatment. Thus, lower-ability learners avail themselves of fewer instructional options, leading to decreased performance under learner control CBI programs.

One recent study investigated the effects of learner control and program control through the variables of full and lean computer-assisted instructional programs between higher and lower-ability students. Schnackenberg and Sullivan (2000) studied third-year university students with content related directly to their field of study. The subjects were 202 juniors at a large university in their first semester in a
teaching preparation program. They were given four treatments: lean and full instruction under program control and lean and full instruction under learner control. The student sample reflected motivated and mature undergraduate learners who were differentiated into higher and lower achievement students based on the Scholastic Aptitude Test (SAT) and the American College Testing Assessment (ACT). Grade Point Averages (GPA) were used to determine high and low achievement for 24 students without SAT or ACT scores. All participants were randomly assigned to one of four program versions within higher-ability and lower ability groups (Schnackenberg & Sullivan, 2000).

Both ability and type of instruction (full or lean) had more of a bearing on performance than the variables of learner or program control. Learner control participants using the full version of the program viewed 30 of 44 (68 percent) of the available screens while learner control participants using the lean version viewed 15 of 44 (35 percent) of the optional screens. Higher-ability learner-control participants viewed 25 (57 percent) of the optional screens and lower-ability control participants view 20 (46 percent) of the optional screens (Schnackenberg & Sullivan, 2000). This difference was statistically significant. Full and lean program versions had a far greater effect on option use than ability. The difference in program use by learner control participants in full program use over lean program use confirmed the researcher’s hypothesis but the lack of significant difference in ability level failed to prove the hypothesis that expected low ability-students to not make good use of learner control conditions (Schnackenberg & Sullivan, 2000).
One implication of Schnackenberg's (2000) study is that a relatively high amount of practice made available in the default mode is likely to be more effective than one that makes a relatively low amount of practice available. This was clearly demonstrated in the superiority of the full program version over the lean program version of the instruction and has been demonstrated in other studies (Freitag & Sullivan, 1995; Hannafin & Sullivan, 1995; Schnackenberg et al., 1998). By using six variables to examine the effect of learner control and using motivated subjects, Schnackenberg's (2000) study demonstrated the ability of learner control to produce achievement results comparable to program control in the full program version, reflecting the optimal use of instruction.

Another recent study, using 380 adult participants, found increased efficiency in using learner control conditions for practice items in computer-based instruction (Shute, et al., 1998). Although students show achievement gains with increased practice in all program treatments, the increased outcome levels for extended practice occurred at the expense of efficiency with a greater amount of learning time expended. Fatigue can easily set in during long tutorials with extensive practice. Adult learners in learner control conditions chose minimal amounts of practice but exhibited comparative gain scores to learners in the most extended practice condition. Shute's study (1998) showed significantly greater efficiency relating gain scores to instructional time for the learner-control group over the fixed-practice condition. These efficiency indices were comparable across both high and low achievers contradicting several earlier findings (Lee & Lee, 1991; Lee & Wong, 1989). Shute's
(1998) findings suggest advantages in offering adult students learner control over practice opportunities.

This research in learner control is relevant to the implementation of Computer-based learning that permits students control in their use and access to the on-line program. Instructors can require students to fully access all the components of the program and monitor this use through electronic tracking, but the use of the program ultimately lies in the students. According to the research, some students may not access all the learning they need. For this reason students should be required to access the full program in the beginning of the academic year, and then given more individual control of their use as they proceed through the year. The on-line programs can be monitored and graded in the Tour to introduce students to all of the instructional screens and then used on an individual or need to know basis, depending on an individual student’s ability and motivation. This allows greater flexibility for individual learning styles.

**Learning Styles Research**

Learning styles are ways in which an individual "absorbs and retains information or skills" (Dunn, 1986, pp. 10-19) Kolb (1981) adds emphasis to the processing and perception of information. Individuals perceive and process information in different ways according their preferred style of learning. Davidson (1990) adds that learning styles are ways of gaining, processing, and storing
information. Learning styles can be studied as overt and observable behaviors that provide cues about how learners process or mediate information.

Students differ in abilities, attributes, motivation and learning styles. Kolb's (1981) Experimental Learning Styles Theory has been widely used with adult students in business and higher education. Much learning styles theory is comprised of two dimensions: how information is processed (active versus reflective) and how it is perceived (abstract versus concrete). The bipolar dimensions of active versus reflective and abstract vs. concrete fall between two poles on a continuous scale. Active learners display tendencies toward experimentation and tend to be extroverts (Kolb, 1984) reflective learners observe prior to making judgments, prefer lecture-type situations, and tend to be introverts (Smith & Kolb, 1986). The abstract-concrete continuum is closely associated with cognitive complexity. Highly abstract learners approach learning analytically and logically (Smith & Kolb, 1986). Concrete learners learn most effectively through specific examples and benefit the most through interaction with others (Smith & Kolb, 1986).

Some studies have demonstrated that learning styles affect student performance. A number of studies at St. John's University that matched learning preference to instructional method led to significantly increased student performance (Dunn, 1986). Other studies have revealed dimensions within learning styles that are relevant to individual performance. Carrier, Williams, and Dalgaard (1988) found the abstract-concrete dimension was significant in predicting scores on note taking scales for college students. Davidson, Savénye, and Orr (1992) found that order (sequential-random) had a significant effect on performance in a computer applications class.
To increase performance, students may require different levels of learner control. Cordell (1991) found an effect in design (linear versus branching). Linear learning requires a sequential path, while branched learning can begin at any point by connecting relevant information through hypertext connections. Learning styles of college students were found to be a significant factor that influenced learning in a hypertext environment (Ellis, Ford, & Wood, 1993). Although more successful learners were sequential, using a step by step process for the first two lessons, significant differences disappeared after the third lesson, suggesting that learners adapt new learning strategies as they become more familiar with the instructional method. This type of adaptive learning may be especially relevant to student mathematics using CBI and CBL approaches. Once students master the process and structure of the essay, they may adapt their subsequent use of the program on a need to known basis by seeking some instruction and by-passing other instruction, resulting in a more efficient use of their time spent in the program.

Current research in learning styles ranges from promoting awareness of various styles to improving learning outcomes and developing alternative instructional methods. Awareness of learning styles can be used to improve computer-assisted instruction designs (Bork, 1988) and adapt instruction to improve performance (Jonassen & Grabowski, 1993). According to Yoder (1994) awareness of individual differences in learning styles is essential to educators. Studies have shown that student performance improves when their learning styles are taken into consideration (Dunn, 1986). By matching learning styles and instructional method, student performance can be enhanced in a computer-based lesson (Riding, Buckley,
Thompson, & Hagger, 1989). Information on learning styles can be used in conjunction with learner control to facilitate and enhance student performance in hypermedia learning environments (Rasmussen & Davidson-Shivers, 1998).

Rasmussen's study examined the influences of the individual difference of learning styles and the concept of learner control to suggest instructional design for all types of learners.

Rasmussen's (1998) study found that learning styles influenced performance in hypermedia learning environments. Active learners preferred lower levels of learner control and performed best in a highly-controlled structure. (Active learners prefer to complete tasks quickly, without distractions.) Reflective learners performed best in a moderate structure of hierarchy with learner control options available. (Reflective learners should be provided structure but also be allowed to explore related instructional material.) Differing levels of learner control should be offered to active and reflective learners. Active learners require more structured learning, while reflective learners should be accommodated by higher levels of learner control to accommodate the association of concepts as desired. Just as one type of instruction does not fit all students, high levels of learner control may prove counterproductive when applied to some learners.

Sales and Carrier (1987) investigated possible interactions among learning styles and feedback preferences of 74 college juniors. They also explored the effects of adaptive feedback on concept acquisition. Four learning style groups were created using Kolb's (1976) Learning-Style Inventory. High scores in active experimentation and abstract conceptualization placed learners in the Converger group. High scores in
active experimentation and concrete experience placed a learner in the Accommodator group and high scores on reflective observation and abstract conceptualization placed students in the Assimilator group. The fourth group, Divergers, had high scores in concrete experience and reflective observation. This information indicates the degree to which learners prefer abstractness as opposed to concreteness and action as opposed to reflection in instructional activities (Carrier, Newell & Lange, 1982).

Three treatment conditions were used in the study: learner control, adaptive control, and program control. In the learner control treatment subjects could select from four feedback options ranging from no feedback to elaborative feedback. In the adaptive control treatment, the opportunity to select feedback was offered only if performance was above a pre-established criteria level; otherwise, elaborative feedback was given. In the program control treatment only elaborative feedback was presented after each response. Data were gathered from each subject on three occasions. Learner control of instruction resulted in students viewing more rather than less material. This result was in contrast to other research conducted by Carrier (1984) with younger children who seemed to ignore or not choose optional instruction. This led Carrier to observe, "older students such as the college juniors in this study might be better equipped to analyze their own information needs and recognize the usefulness of analytical feedback" (Carrier, 1988). The difficulty level of the lesson may also have influenced students' selection of feedback. When instruction is perceived to be difficult, learners seek out more instructional support (Tobias, 1982). The subjects in the learner control treatment indicated a preference.
for the two most elaborate forms of feedback available. The locus of feedback control had no significant effect on learner achievement revealing that students can make the right choices under control of their own learning.

Research on Instructional Design

Although the literature on the effects of media on learning is inconclusive, the design of instruction can affect learning in both traditional and online settings and delivery methods. Some design principles that may affect student success in online learning include: the perceived relevance of the course; the amount of interaction with instructors, tutors and other students, the difficulty of the program and time involved; the nature of the media used for delivery and interaction; and the amount and nature of feedback received from instructors (Moore & Kearsley, 1996). In addition to these success factors, technical support can also be added to keep CBL environments running smoothly for student access in classrooms, labs, and home.

Consideration of student expectations should guide course design, implementation, and student support services. Students expect current and authoritative information, courses that are flexible and can accommodate various learning styles, and timely feedback on their work and progress (Moore & Kearsley, 1996). The role of the instructor for feedback and evaluation is a key ingredient in online and computer-based learning. Research on prior knowledge has shown the importance of considering the learner's level of competence and previous knowledge.
Learning outcomes and goals should be clearly stated. Instruction should be motivating, provide for multiple contingencies, be logically sequenced, and based on student needs. The learner should be actively involved in learning (Thompson, et al., 1996). In addition to these critical success factors, learners need to be "self-regulated" or self-directed to be successful in online and computer-based learning networks (Brooks, 1997).

To provide guidance for real classroom practice and be held accountable for effectiveness, research in computer-based learning must be both rigorous and relevant. Rigor involves adherence to the principles of empirical science. All researchers must follow specific methodologies that can be strengthened or refuted by further empirical studies (Reeves, 1997). Theoretical research in computer-based learning and learner control can offer a foundation for evaluation to come to understand new products, programs and methods applied to specific educational settings.

Learning can be defined as a process through which learners systematically and strategically organize their domain-specific knowledge in order to construct mental models. Media cannot influence learning directly, but they have an indirect and subsidiary effect. The format in which information is presented and the case with which it can be comprehended may be decisive in facilitating learning (Dorr & Seel, 1997).
Hasselbring (1986) conducted research on the effectiveness of computer-based instruction (CBI) conducted over the past two decades. Using student achievement as a dependent measure, the research on CBI is reviewed by him under the headings of evaluative studies, summaries of the proportion of studies favorable and unfavorable to CBI ("box-score reviews") and meta-analyses. Conclusions are drawn as to the effectiveness of CBI with regard to academic and social achievement. Finally, a cost analysis of CBI is given by him.

The researcher has concluded that "...First, there is evidence that computers can be used to effect positive student gains in all curricular areas, but especially in mathematics. It also seems that CBI is especially powerful for disadvantaged and low-achieving students. It is clear that computers do not stifle the creative process, are not dehumanizing, and do not foster anti-social behavior or development. However, none of the potential benefits of CBI are inherent. On the contrary, the greatest gains from the use of the computer seem to occur when it is integrated thoughtfully into the on-going curriculum and not used as a replacement for existing courses. While CBI has reduced the dependence of instruction upon the quality of human effort to some extent, human effort and quality instructional materials still remain the major factor in the successful or unsuccessful use of computers in education."

In a study by Randall E., Schumacker, Jon I. Young, and Karen L. Bembry (1995), the difference in Algebra I exam performance, mathematics anxiety, attitude
towards success in mathematics, and confidence in learning mathematics, for the computer-instructed students and students using the traditional lecture method of instruction was examined. The traditional lecture group on the average scored higher than the computer-instructed group in mathematics, but that might have been because the commercial software used did not cover all the concepts. There were no apparent differences in mathematics attitudes, anxiety, or confidence.

A study entitled “Classroom Instruction Differences by Level of Technology Use in Middle School Mathematics” was conducted by Hersholt C. Waxman and Shwu-Yong L. Huang in 1996. This study examined whether 1) classroom interaction, 2) selection of activities, 3) instructional activities, 4) organizational setting of the classroom, and 5) student on-task and off-task behaviors in the classroom significantly differs according to the degree of implementation of technology in mathematics classrooms. The subjects in the present study were 2,189 middle school students who were randomly chosen from a multi-ethnic school district located within a major metropolitan city in the south central region of the United States. The results indicate that there are significant differences in classroom instruction by the amount of technology used. Instruction in classroom settings where technology was not often used tended to be whole-class approaches where students generally listened or watched the teacher. Instruction in classroom settings where technology was moderately used had much less whole-class instruction and much more independent work. These findings are quite similar to previous research that supports the notion that technology use may change teaching from the traditional teacher-centered model to a more student-centered instructional approach. Another important finding from
the present study is that students in classrooms where technology was moderately used were also found to be on task significantly more than students from the other two groups.

The effectiveness of a computer program “FUNdamentally Math” was evaluated by making statistical comparisons of students’ mathematics achievement on the State of North Carolina’s (USA), required end of grade and end of course test. The study was conducted over a two-year period of 1997-1998 and 1998-1999. The study involved students from three schools in eleven different classes. The software was utilized in numerous ways. The software covered all areas of mathematics. Pre-test and post-test scores on the State end of grade examination for the students were collected. The author of the study utilized a two-tailed T test to determine if a significant difference was present. The study demonstrated that the students who utilized the computer software scored significantly higher than the students who did not participate did at a 99.5% confidence level. The algebra students using the software made 17% jump in scores (Brown, 2000).

Another study on the effects of CBI on students was published by Abbas Johari (1998). Johari’s subjects were 98 secondary school students in 2 sections of a Precalculus class. The students were randomly assigned to 1 of 2 treatment groups. One group substantially more computer based instructions. The other group was taught in the traditional lecture method. Johari gave each group a pre-test and a post-test. The group that received the computer based instructions scored significantly higher on the post-test. The author drawn the conclusion that a relationship exists
between the use of computer-based instructions and achievement of students of mathematics.

In a study by Mascuilli (2000) on effectiveness of Teaching mathematics online, the researcher has used three modes of communication with students who took an on-line mathematics course. By making use of e-mail, chatting and telephone facility as communication for the course, the researcher has compared the results of final test of on-line students with the group of same course who were taught traditionally on campus. Using two-sided hypothesis test, the researcher has concluded that there was significant difference on achievement of both the groups. The on-line group scored higher significantly. The results of this study on the success rates support the claim that on-line (CBL approach) teaching is a legitimate and reliable method of teaching mathematics.

According to Anzalone (1986), the University of the West Indies evaluated PLATO instruction given to participants in the Human Employment and Resource Training (HEART) program in Jamaica. The evaluation found a 50% difference in favor of students receiving PLATO instruction at the Stony Hill Commercial Skills Academy when compared to students receiving conventional instruction in basic skills. Ninety-six HEART Trainees (aged 18-24) who scored below 50% on a basic mathematics skills placement test took part in the study. Trainees were randomly assigned to a PLATO group and a control group. The 47 students in the PLATO group received 28 hours of computer-assisted instruction in basic mathematics skills. The 47 students in the control group received 28 hours of math instruction using self-
paced competency-based materials developed by the USAID Basic Skills Project. Each group had a different teacher.

Both groups took the Adult Basic Learning Exam (ABLE Level II Form A) and ABLE Level II Form B as a post-test. Statistical consultants R. A. Mitchell and W. S. Buckley of the University of the West Indies analyzed the results of the evaluation. They concluded that if the experiment were to be repeated under similar conditions, in 99 out of 100 repetitions, the PLATO users would perform at least 50% better than students receiving traditional teaching.

The report of CBE Research Lab. (982-83) describes activities of the PLATO Education Group (PEG), the educational research and development arm of the Computer-based Education Research Laboratory (CERL) at the University of Illinois at Urbana-Champaign. Staff, funding sources, and an overview are presented for the four projects summarized, along with additional, project-specific information (parts of the PEG courseware were predecessors of some current TRO PLATO courseware). The PLATO Corrections Project (PCP) provides inmates of Illinois adult correctional facilities with access to basic skills instruction and to instruction in several vocational and a few advanced academic areas. A description of PCP discusses outreach, noteworthy features and problems, curriculum development (reading, language, and mathematics), the SYS IV instructional management system, PCP instructional design research, and future plans.

The PLATO Mathematics Project is involved in courseware research, development, implementation, and evaluation on basic mathematics. Qualitative interpretation of graphs for students of basic sciences and prototype computer
courseware for teaching high school algebra are subtopics in this section. Additional projects summarized are the Continuing Study of the Use of Computers in Mathematics Instruction, and the Handicap Technology Program. References are listed for each project summary.

A study by Dixon (1990) analyzed two methods of instruction in Fundamentals of Mathematics, a remedial math course required of all entering HCC students who do not pass a math proficiency test. For the control group (46 students), the instructor was the primary facilitator of instruction. The experimental group (35 students) used PLATO computerized instruction and management in a lab with tutorial help available on request during specified hours. The PLATO courseware and the classroom syllabus were both aligned with the Texas standard (TASP) curriculum, and were determined to be equivalent in content. Classes in the control group met for 2 hours per day, 4 days per week, for 6 weeks.

The testing instrument used in this study was the Arithmetic and Basic Skills Test developed by the Committee on Placement Examinations from the Mathematical Association of America. The following statistical tests were used: 1) Spearman Correlation for relationships; 2) T-Test for differences; and 3) means, range, variance, standard deviation, coefficient of variation, skewness and kurtosis tests were used for the other general comparisons. The results are given as under:

i. The control group had a mean gain of 5.2 (s.d. = 3.84)

ii. The experimental group had a mean gain of 7.8 (s.d. = 5.63)

iii. The t statistic of 2.47 was significant at p = 0.015 for 79 degrees of freedom
iv. In percentage terms, the control group showed a 14.4% gain, while the PLATO group showed a 24.4% gain.

v. In regression test, a beta of 0.10 was attributed to the experimental treatment ($p < .001$).

vi. The mean number of hours per student in the experimental group was 27.23.

vii. The range of hours per student was from 10 to 60.

viii. Spearman correlation of hours of usage and amount of gain was $0.27 (p = .015)$.

This compares with a fixed instructional time of 48 hours for the control group.

In summary, the PLATO group showed a 10% larger learning gain, with approximately half the instructional time. This indicated both increased effectiveness and efficiency for PLATO.

In 1987, in the Lost Students (1991), Dayton Public Schools, Dayton, Ohio, installed PLATO computer-based learning systems at Longfellow Alternative High School to serve the educational needs of students who were not functioning successfully in a conventional school setting. The primary reason for selecting PLATO, according to District Superintendent Dr. James Williams, was because PLATO effectively addressed the needs of secondary and adult student populations. The district (in 1990) released information showing the standardized test scores have increased at nearly every grade level, showing that standardized test scores have increased at nearly every grade level, especially in mathematics. District personnel believe that the use of technology products, including the PLATO system, has contributed to these improvements.
According to Poore (1983), in an experiment conducted during 1979-80 by the Computer Center at Florida State University in cooperation with the Florida Department of Education and funded by the Florida Legislature, the PLATO Basic Skills Learning System for Mathematics produced significant gains at both the middle and high school levels with greater gains at the middle schools. The project included seven high schools and two middle schools using PLATO for a two-year period.

Based upon the gains in the experiment, the authors believe that PLATO is an effective medium for improving mathematical skills at the middle, junior and high school levels for students needing remediation.

The EPGY Program

The Education Program for Gifted Youth (EPGY) at Stanford University is a continuing project dedicated to developing stand-alone multi-media computer-based courses and offering these to remote advanced middle-school and high-school students through Stanford Continuing Studies in USA. Since 1992, EPGY has taught advanced placement calculus and physics to over 600 advanced middle school and early high school students. The EPGY program has been very successful globally. It has 3500 students in different courses from all over the world. The EPGY is being used in various countries including Mexico, Singapore, Hongkong, Australia and in USA.

The EPGY uses information technology to provide students with a venue to utilize and groom their intellectual development. More importantly, it does so in a
way to increase the academic performance of the students without disturbing the regular schoolwork of the students.

The EPGY course use multimedia technology. The software presents lecture environment consists of interactive multimedia exposition, on-line exercises using symbolic computation, and automated reasoning to check student work. The course environment also contains facilities for collecting extensive data on all aspects of actual student usage of the software. Every time a student views a lectures, answers a question or proves a theorem, all relevant information concerning this event is preserved. The students send this information by e-mail to Stanford where it is automatically seeded into a database. This data collection allows course developers to isolate those areas in the course where students are having the most difficulty, so that they can refine them by adding new material to explain common mistakes, or by adding more detailed explanations to areas generating the most questions. It also makes it possible to see which features of the software prove useful to students and which are sources of frustration

_Aim of EPGY_

The Education Program for Gifted Youth (EPGY) at Stanford University aims to provide year-round, accelerated instruction in mathematics and physics to students via a computer, thereby allowing students to complete the course work. Because the program is computer-based it places no limits on the number of participants at a site
and indeed does not restrict participation to students living in any particular location or country

**Nature of EPGY**

EPGY students run the multi-media courseware at home or in school on standard IBM-compatible personal computers. This software, unlike traditional computer-based educational programs, is intended to stand alone, not merely to supplement a regular class (Ravaglia, 1995). The computer presents lectures using digitized sound and graphics, in essentially the same way that a human instructor would. These lectures are followed by on-line exercises that gauge the student's understanding, as would a teacher in front of a classroom, but in greater detail. Students' only direct contact with instructors is electronic, via electronic mail and telephone contact with centrally located project staff like the one at HKS Institute of Mathematical Sciences located in Islamabad, Pakistan.

**The Evolution of EPGY – From CAI to CBI**

EPGY evolved from two distinct strands of research conducted at the Institute for Mathematical Studies in the Social Sciences IMSSS at Stanford University (USA), under the direction of Professor Patrick Suppes. One strand involved computer-based education; the other involved the education of gifted children.

Computer-based projects at IMSSS have included instruction in mathematics from elementary arithmetic to college level logic and set theory, as well as courses in
a number of languages, including Russian and Armenian. These projects are reviewed extensively in Suppes (1981). These early studies demonstrated that students can benefit significantly from on-line instruction, whether the computer merely provides drills on concepts learned in the conventional classroom or provides a complete tutorial format including both exposition and practice. Moreover they showed that among students of all levels and abilities there are significant differences in the rates at which students will move through the courses, demonstrating the importance of an adaptive curriculum sensitive to individual differences. A detailed examination of these points for both students in the secondary school and university levels are given in Larsen, Markosian and Suppes (1978) and Suppes, Fletcher and Zanotti (1976).

IMSSS also conducted investigations in mathematics concurrent with, and sometimes coincident with, these early experiments in computer-assisted instruction. In the first such study, conducted in 1955, students in the ninth grade were invited into an introductory logic course, at Stanford. These accelerated high school students performed at the same level as the college students. A later, more ambitious project involved a longitudinal investigation of an accelerated program in mathematics for elementary students conducted from 1963 to 1967 (Suppes, 1966, Suppes & Hansen, 1965, Suppes & Ihrke, 1967, 1968). The program began with a group of first graders who worked at their own pace through mathematics textbooks (Suppes, 1963, 1964, 1966), attended classes, and worked on a variety of supplemental materials, some of it computerized. Students were exposed to topics and concepts not normally taught at the elementary levels, such as logic and geometric constructions, in addition to abundant drill in the traditional curriculum.
Several striking findings emerged from this investigation. First, students on
the whole worked very quickly through the materials presented. Nevertheless, they
varied widely in the rate at which they worked through the self-paced materials by the
end of the fourth year; two textbook years separated the fastest from the slowest
participant. Students also differed widely in the proportion of errors they committed,
though there was surprisingly little correlation between speed of progress and number
of errors committed. Especially notable, particularly given the disparity among
student work rates, was the uniformly high scores they achieved on standardized tests
keyed to the material they had completed. These findings highlight individual
differences in learning rates even among the gifted, and consequently stress the need
for self-paced materials to allow each such student to perform at his or her maximum
achievement potential. The present Education Program for Gifted Youth grew out of
this research in computer-assisted instruction. Development of what later became the
EPGY courses began in 1985 at IMSSS, funded by a grant from the National Science
Foundation, USA as proof of concept demonstration that a first-year college calculus
course could be entirely computer-based (US. Department of Education, 1993). The
original motivation to design an online calculus course was the fact that fewer than
25% of the high schools in USA currently offer calculus; the idea was to make this
course available at schools having interested students but either no one qualified to
teach them or no money to justify having a small class for just a few students.
Course Design

All EPGY courses use computer-based methods as the primary vehicle of instruction, although some assistance from a tutor who can discuss or correct on-line work, grade tests and certify performance in the course is required. The following course components are on-line: a complete, interactive, multimedia exposition of the curriculum material involving digitized sound and graphics, an interactive problem-solving environment, mastery quizzes, problem sets, and databases of off-line problems. All the courses incorporate the Maple computer algebra system (Char, 1988) as the internal computational engine for doing algebra and calculus operations. Along with the engine for symbolic computation, the courseware incorporates a curriculum driver, authoring system, interactive interface for calculus problem solving, and graphing facilities.

Working of EPGY Software

For each topic within a course, the computer first presents an interactive textual exposition in the form of a brief lecture (usually under 5 minutes) consisting of digitized sound recordings along with handwriting or formatted text and graphics that appeared on the computer screen in real time, more closely resembling what a teacher would write on a chalkboard while lecturing. These lectures alternate with a set of interactive exercises, such as a set of questions about the preceding lecture, interactive exposition in which the student is led through a detailed argument step by
step, or a derivation in which the student is asked to prove a mathematical fact. One lesson generally comprises three or four lecture-exercise units.

It is stressed in the program that the amount of material presented to a given student varies according to that student's rate of mastery of the material. After the computer has presented the initial instructional material, students are given exercises testing their understanding of that material. Depending on their responses students either proceed to the next subject or receive focused remediation until they understand it. This technique of quick presentation followed by diagnostic tests and additional instruction tailored to the student's weaknesses has been demonstrated to be a crucial aspect of EPGY, which are geared for allowing students to accelerate rapidly (Stanley, 1991). Students do on-line work in addition to their on-line lessons. In fact, for each half an hour they completed on-line, participants spent as much as 15-20 minutes doing additional off-line homework-reading and exercises in traditional texts (Anton, 1988) and (Tipler, 1991) - both to give them more practice with the material and to help them prepare for off-line examinations.

At the end of a lesson topic, the computer presents another quiz on material covered since the previous quiz. Additional remediation is provided to those students needing it. For the students reported on here, off-line examinations are administered at the end of every chapter (corresponding to chapters in the text). The complexity of the exams varied from simple 60 minute in-class exams to take-home exams to be turned in a week later.

It should be evident that the tutorial role of the computer in EPGY courses is considerably more central than the role technology frequently plays in mathematics or
science education. The computer in this program is no mere computational aid, electronic textbook, or drill assistant. Nor is it an enrichment supplement like a mathematics or physics lab or optional aspect of another instructional modality. Rather we sought and continue to seek to exploit the technology as fully as possible to produce stand-alone courses that capture and maintain students' interest while efficiently teaching substantial academic content.

From the students' viewpoint, the computer manages the courses, but in important ways students must manage themselves more than they would in a classroom or live tutorial setting. Students must find their own pace, take action when difficulties arise, and keep up with course requirements. Subject to several examinations or milestones during each semester of the full-year course, students have flexibility in pace, workload, and help from human tutors. In particular, they are free to spend as little or as much time as they need to master material. It is recognized that the self-regulatory aspect of the EPGY courses may prove beneficial for some students but not for others. The past experience of EPGY with self-paced courses, including twenty years of running a self-paced course in logic at Stanford has taught us that monitoring student progress and periodic personal contact are necessary to motivate students who might otherwise tend to procrastinate. These points are discussed more completely in Macken, van den Heuvel, Suppes, and Suppes (1976) and Suppes (1981).
The EPGY Course Software

The EPGY courses are completely computer-based. They are distributed on two or more CD Roms and are designed to run locally. Each course consists of lessons which correspond to the logical sections in a text book. Lessons begin with a multi-media presentation in which digitized sound is played and synchronized in real-time with the display of graphics to create what resembles a teaching writing on a blackboard while lecturing. Students have full control over the lectures being able to pause, fast-forward and rewind at any time. Students can control several lecture parameters including the speed of the lecturer’s voice and the format of the graphic display. It is worth noting that these lectures have been designed so as to preserve the informal nature of spoken mathematics or physics as contrasted with the more formal prose style of text books in these subjects. This is important since it has been observed by many people, though never adequately researched, that oral lectures are an important part of learning the mathematical and physical sciences. Such informal lectures are important; they allow the students to absorb matters of style, such as how to talk informally about the subject, how to draw diagrams, and how to write equations.

The lectures are followed by a set of simple questions, which review the students’ understanding of the material just presented. After these review questions students are presented with a set of interactive exercises, which consist either of a quiz on the material covered in the lecture, interactive exposition in which the student is lead through a detailed argument step by step, or a derivation in which the student
is asked to obtain the answer to an exercise. As one would expect, the difficulty level of the exercises increases as the student progresses into a lesson. Depending on its complexity the student may have to make several intermediary computations. These computations can be done either with paper and pencil or by using our Derivation System.

**Salient Features of EPGY**

i. **Assessment, Feedback and Symbolic Computation**

The ability to provide students with immediate feedback to their work is one of the great strengths that computer-based courses have. Immediate feedback is particularly important in the distance-learning context where students face additional difficulties in submitting and retrieving written solutions to problems. Providing immediate feedback requires the ability to assess student work. Ideally this should include assessment both at the level of being able to answer standard questions, as well as understanding why a solution is correct. The types of questions students are asked in the course are of the sort that instructors traditionally ask after lectures or on examinations. They consist predominately of questions requiring closed-form mathematical expressions as solutions, though we have been experimenting with interactive proofs and will discuss these below. In free answer questions several issues must be taken into consideration (Nicaud, 1992).

One important issue is ease of input. If students have to type complex mathematical expressions in an input language, the odds that an incorrect response is
caused by an error in typing will make meaningful evaluation impossible. Care must be taken to provide students with a convenient means of input that does not require a great effort to learn, together with the ability to see their input formatted, so that they can verify that what the computer has understood is in fact what they wished to express. The EPGY structural input system addresses both of these concerns.

Another issue is flexibility in answer form. Students should not have to constrain their answers to fit a particular form, outside of those constraints which an instructor would reasonably place upon them in a traditional class. The correct approach is to process the answers symbolically, taking into consideration their mathematical meaning, and considering possible correct answers in terms of equivalence classes. This minimizes the need to require that students conform to an arbitrary input standard, allowing the computer to understand natural variations of correct answers, thereby accommodating different approaches to a problem, which can result in equivalent correct answers with different forms.

A simple example from the first year of algebra shows the range that a student's answer can take. Suppose a student is asked to factor the expression $12t^2 + t - 35$. One will likely want to accept as correct any of the following answer variants: $(3t - 5)(4t + 7)$, $(4t + 7)(3t - 5)$, or $(5 - 3t)(7 + 4t)$, not to mention several others with essentially the same form. On the other hand, the response $t(12t + 1) - 35$ should be rejected. Whether or not the student's answer is correct can be determined by passing the student's input and the author-coded answer plus specification of equivalence class to a symbolic computation program for evaluation and comparison. Exploiting the
fact that the answers are mathematical expressions increases the flexibility for student
input and simplifies author coding.

An additional benefit of this approach is the ability to automatically diagnose common student errors. There are a number of almost correct and incorrect answers that deserve special treatment. Errors in choice of variable, e.g. \((3x - 5)(4x + 7)\), errors caused by transposition of a factor or of the minus sign, e.g. \((4t - 7)(3t +5)\), or \((3t + 5)(4t - 7)\), should be detected so that the mistake made by the student can be explained.

A more difficult problem than determining if a student's answer is correct is that of evaluating the student's entire solution. The link between understanding and the evaluation of work at this level is the sentiment back of the perennial dictum of "show your work." One step EPGY has taken towards being able to perform this sort of evaluation has been to make use of an interactive derivation system. The derivation system is an environment in which students can formally manipulate mathematical expressions by applying inference rules. A derivation system differs from a raw symbolic computation environment, such as Maple or Mathematica, by having the logical structure necessary to represent mathematical inference and logical dependency. This enables the derivation system to detect when students make fallacious inferences while working a problem. In the environment the student supplies the rule and the derivation performs the appropriate calculation. The results of the calculation are preserved for the student to further manipulate. A derivation of a problem is the set of steps from the statement of the problem to the solution. By requiring students to explicitly justify their inferences, it becomes possible to examine
the process that a student goes through to produce an answer and not just the answer itself.

**ii. Improving Remote Interaction with Human Instructors**

Even though the goal of EPGY is to automate as much of the instructional process as possible, interaction with human instructors remains an important component of the EPGY course model. Traditionally this interaction has been provided by asynchronous means such as telephone and e-mail. While effective, they constitute only a first step in providing robust interaction between instructors and students. There are several points to be made on this subject.

The first point is ease of communication. Any time a student wishes to send e-mail from within the course he or she may do so by simply selecting an option from a menu at the topic of the screen. The program will automatically append to this message the student's name and exact location in the course. This makes it possible for students to say things like "I do not understand this exercise" without having to figure out how to describe the exercise in question.

An important component of e-mail communication in these courses is the ability to send graphics and sound in addition to text. The illustration above shows a message sent by a student to an instructor in the multivariable calculus course. The student has taken the screen image from the lecture she was in and has annotated it using a graphics tablet. The instructor has made his own annotation to her message as part of his reply. The student or the instructor could have included digitized sound in
the message as well. Allowing handwriting and speech in messages makes asynchronous mathematical communication much more natural and it also frees students from having to learn outmoded linear notation.

There is need to move beyond viewing asynchronous communication as the ideal mode of student/teacher interaction in the distance learning context. For the last several years it is experimented with using a variety of shared whiteboard conferencing environments in conjunction with internet telephony to create a cost-effective virtual classroom. In this virtual classroom one has the essential elements of any mathematics classroom: one has a common space on which to write (in this case the computer screen rather than the chalkboard) and one can talk whenever one is given permission to do so. The virtual classroom allows for the sort of immediate teaching experience that is common in traditional office hours or discussion sections, but which is usually thought of as unobtainable in the distance-learning context. It is expected that this feature, as it becomes thoroughly integrated into our courses, to have a profound impact on both future education and future course development at EPGY.
Chapter - III

METHODOLOGY AND PROCEDURE

Methodology

The present study was aimed at investigating the comparative effects of use of information and communication technology in teaching of mathematics through three different approaches - the Computer Based Instruction, Computer Based Learning and Teacher Centered. Since the study required the manipulation of the experimental variables hence experimental research method was the proper choice.

Research Design

The Posttest-Only Control Group Design was considered more appropriate for this study (Hatch and Farhady, 1982). The reason for this choice was that this design has the potential to control most of the variables affecting internal and external validity such as contemporary history, instrumentation, differential selection of subjects and statistical regression reactive effects of experimental procedure through randomization and match grouping (Mertens, 1998). While mortality is a potential threat to validity with this design, it did not prove to be a threat in this particular study since the group sizes remained constant throughout the duration of the study and the study was relatively short in duration. The selected topic of mathematics was not
taught in any class from I to VIII and this topic is first time introduced at the secondary level, therefore, it was assumed that neither group had any knowledge related to the dependent variables and the posttest-only design found most appropriate for this study (Gay, 1999).

**Research Questions**

The design of the study permitted to investigate the following questions:

**Question on Achievement and Retention**

AR Is there a difference on mean score among the achievement and retention of the students of secondary level taught mathematics through CBI, CBL and TC approaches?

**Questions on Achievement – Posttest**

A1 Is there a difference among the achievement of the students of secondary level taught mathematics through CBI, CBL and TC approaches?

A2 Is there any significant interactions (of achievement) among the types of teaching approaches (CBI, CBL and TC), students’ ability (below average, average and above average) and gender (boys and girls)?
A3 Is there a difference among the achievement of the students of secondary level taught mathematics through CBI and CBL approaches?

A4 Is there any significant interactions (of achievement) among the types of teaching approaches (CBI and CBL), students’ ability (below average, average and above average) and gender (boys and girls)?

A5 Is there a difference among the achievement of the students of secondary level taught mathematics through CBI and TC approaches?

A6 Is there any significant interactions (of achievement) among the types of teaching approaches (CBI and TC), students’ ability (below average, average and above average) and gender (boys and girls)?

A7 Is there a difference among the achievement of the students of secondary level taught mathematics through CBL and TC approaches?

A8 Is there any significant interactions (of achievement) among the types of teaching approaches (CBL and TC), students’ ability (below average, average and above average) and gender (boys and girls)?

Questions on Retention – Delayed Posttest

R1 Is there a difference among the retention of the students of secondary level taught mathematics through CBI, CBL, and TC approaches?

R2 Is there any significant interactions (of retention) among the types of teaching approaches (CBI, CBL and TC), students’ ability (below average, average and above average) and gender (boys and girls)?
R3 Is there a difference among the retention of the students of secondary level taught mathematics through CBI and CBL approaches?

R4 Is there any significant interactions (of retention) among the types of teaching approaches (CBI and CBL), students' ability (below average, average and above average) and gender (boys and girls)?

R5 Is there a difference among the retention of the students of secondary level taught mathematics through CBI and TC approaches?

R6 Is there any significant interactions (of retention) among the types of teaching approaches (CBI and TC), students' ability (below average, average and above average) and gender (boys and girls)?

R7 Is there a difference among the retention of the students of secondary level taught mathematics through CBL and TC approaches?

R8 Is there any significant interactions (of retention) among the types of teaching approaches (CBL and TC), students' ability (below average, average and above average) and gender (boys and girls)?

*Population and Sample*

The population of the study was comprised of students of class nine studying mathematics. For the purpose of selection of the schools of the study, a letter of request was written to Director General Federal Directorate of Education (FDE), Islamabad. Accordingly, the Director General, FDE gave permission to conduct this study in the two schools and to include the selected students to participate in the
study. The FDE also informed the Principals of selected schools to extend their cooperation to the researcher for this study without disturbing their timetable.

The reasons for taking sample from only two institutions were that 1) for the first time, the FDE Islamabad has conducted centralized examination for class VIII. This examination provided a uniformity and base line of having students of all ability level in each institution. Therefore, the two selected institution represented all schools of Islamabad, 2) the revised scheme of study for the secondary schools has tightened the schools schedules and do not permit to disturb schools time tables, 3) this study involved various components of information and communication technology and logistics which was not possible to arrange in more than two institutions in available time frame.

The selected institutions were equipped with better facilities and heads of these schools were willing to cooperate for this study. The group, ability and gender distribution of sample is given in table 2 below:
Table 2

*Group, ability and gender distribution of sample*

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of students</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Below Average</td>
<td>Average</td>
</tr>
<tr>
<td></td>
<td>Boys</td>
<td>Girls</td>
</tr>
<tr>
<td>CBI</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>CBL</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>TC</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>12</td>
<td>3</td>
</tr>
</tbody>
</table>

*Group Formation*

Complete section of class IX students from each of the boys and girl school were taken for the study. On the basis of the marks obtained in final examination of class VIII centrally conducted by FDE, Islamabad, the students were first categorized into mathematical ability level according to the criteria given as below:

- **Below Average**: Marks below 50
- **Average**: Marks 50-70
- **Above Average**: Marks 70 and above
After determining the ability level of each of the students of a section, the students were equally distributed (Appendix-E) into three group viz. CBI, CBL and TC using the basket method.

**Research Locale**

The following Secondary Schools of Islamabad were selected for conducting the experiment:

1. Islamabad College for Boys, G-6/3
2. Islamabad Model College for Girls, F-7/4

The schools were selected for the experiment for the following reasons:

i. These schools situated near to each other;

ii. In one school, the computer laboratory was available and in other school, it was easy to manage all computer related equipment;

iii. The selected teachers belonged to these schools;

iv. The Principals of these schools showed great enthusiasm in the study and offered their willingness to give computer laboratories and facilitate the teachers and students,

**Selection of Teachers**

Three teachers from each of the boy and girl’s school were selected for the study. For the purpose of selection of teachers, the Principals of these schools were
requested for nomination of average secondary level mathematics teacher from their schools. The Principals of these schools nominated the teachers who voluntarily agreed to render their services for the study.

*Orientation and Training for Teachers*

The National Institute of Science and Technical Education (NISTE), Ministry of Education, H-8/1, Islamabad, was selected as venue to conducted one-week program of orientation and training (Appendix-C) for the teachers involved in the experiment. Out of six days program, one day was reserved for general orientation of all teachers of the three groups. In this orientation, the researcher explained the objectives and procedure of the study. The teachers were informed that the chapter on “Concept of Matrices” would be taught to selected students of their group. The teachers were given the Program (Appendix-A) and time table (Appendix-B) of the experiment.

The teachers of control group were specifically told not to use computer or any related technology such as e-mail and Internet during their teaching to the selected group.

After general orientation of all six teachers selected for the experiment, the four teachers of the reference were given intensive training of two days for using approaches of Computer Based Instructions (CBI) and Computer Based Learning (CBL).
The teachers of CB1 and CBL approaches were explained that they have to make use of the following during their instruction:

i. Chapter on “Concept of Matrices” of mathematics of textbook for classes IX-X with sub-topics: Matrix and order of a matrix, types of matrix, operation of matrices, multiplication of matrices, determinants and some other types of matrices and solution of simultaneous linear equations.

ii. EPGY Software related to the topic.

First of all, the teachers were explained the procedure of using EPGY software including starting, going back, forwarding, browsing and closing the software. The accent and the key terms of the software were got recognized to them. They were explained the notations and symbols to be used in self-assessment.

The teachers were given opportunity to run and use the software at their own. The teacher got enough time for hands on software and interaction with each other.

In last three days of the week on training of the teachers, the teachers of CBL groups were given training on making use of information and communication technologies in order to be in position to make the learning interactive through e-mail, chatting and to link with web sites and internet resources. During the training, these teachers were given demonstration and opportunities to get access to different resources of mathematics and mathematics teaching around the world.

A live Homework help was provided to the teachers of CBL group through http://www.tutor.com/. This help line service was arranged to allow the students to connect to qualified tutors up to 20-minutes as part of live tutoring sessions from
USA every day during break period. The teachers got accesses to different tutors for seeking help in solving the problems of students related to the topic.

The teacher of CBL group were trained in composing mathematical questions, assignments. The teachers of the groups were also trained for chatting and in making the e-mail addresses, sending, receiving and replying the e-mail messages of their students.

Orientation of Students

For the purpose to give treatment to the CBI and CBL groups. It was felt necessary to give orientation and hands on opportunity to the students of these groups on use of computers. A one-week program (Appendix-D) was therefore organized for the students of CBI and CBL groups.

A teacher of computer science of their school familiarized students with the fundamentals of computer such as introduction to Peripheral devices, getting starting on PC and introduction to MS office. During one-week orientation in the break time, the students got well enough opportunity to know about the computer and its use.

The students of CBL groups were familiarized with use of e-mail, chatting and Internet. The e-mail addresses of all the students of this group were made. The students of this group were trained in composing mathematical questions, assignments, sending, replying and receiving the e-mail messages of the teachers and to get link on-line with tutors.
During the orientation, the students of these groups were given demonstration and opportunities to get access to different resources of mathematics and mathematics teaching around the world.

**Instruments**

Two instruments were used for the collection of data required to answer the research questions. These were i) Posttest, ii) Delayed posttest.

**Posttest**

This instrument was developed to measure the achievement of students of all three groups on the topic taught to them during the study. The test was based on the content of mathematics, chapter “Concept of Matrices” taught to the students during the experiment. This test comprised of two parts. Part-I comprised of 15 items Multiple Choice Questions (MCQs) and Part-II contained 6 problems (Appendix - G).

**Development and Revision**

The development and revision of posttest was carried out according to the procedure described as below:

a. Initially the posttest was developed with the help of two working teachers who has been teaching mathematics to the secondary classes for a long time;
b. On the draft posttest, comments of 38 Lead Master Trainers (LMTs) of mathematics were received. These LMTs were very senior mathematics teachers, nominated by the Provisional and Federal Governments and were under training for four months in NISTE;
c. The posttest was revised in the light of comments of LMTs;
d. The revised posttest was again improved by 10 senior most selected LMTs;

Validation

A draft of the posttest was submitted to the Advisor of the study for his feedback and critical review. The observations, comments and critique of the Advisor proved to be helpful for the improvement of the posttest. In addition, the instrument underwent Jury of three experts for content validation described as below:

a. The content of the posttest was validated by a senior mathematics Professor of F.G. Degree College, H-8, Islamabad;
b. The Multiple Choice Questions (MCQs) of the posttest were validated by an educationist of Allama Iqbal Open University, H-8, and Islamabad;
c. The pattern, format and weightage of post-test was also validated by a senior teacher and Paper setter of Board of Intermediate and Secondary Education of a F.G, High School, Islamabad;
Delayed Posttest

The delayed posttest (Appendix-I) was developed for the purpose of measuring the retention of the topic taught to the students of all groups. This test was form of posttest. A table (Appendix-F) of random numbers was used to randomize the sequence of the questions of the posttest (achievement) and delayed posttest (retention). Changing the sequence of questions and the time interval between administrations of the two tests reduced the sensitization to the instrument.

Pilot Testing

The pilot testing of posttest was carried out in two stages (a) one to one testing (b) small group testing.

Individual Testing

The researcher approached a mathematics teacher of secondary level of F.G. Model Secondary School for boys (G-9/4, Islamabad) through the Principal of the school and requested him to recommend an average student of class-X in his eye for pilot testing. The student had already studied the chapter on “Matrices and Determinants” in class IX. The student was given this test and he was asked to follow the instructions of the test and feel free to answer the questions. Difficulties faced by the students during test taking were noted and discussed with him.

Later on, the noted difficulties whether of content or language were removed.
Small Group Testing

The small group testing of posttest was executed on eight students of two secondary schools one boy and one girl. The students had already studied the related chapter. The sample distribution is given in table 3 below:

Table 3

*Sample distribution of small group testing*

<table>
<thead>
<tr>
<th>School</th>
<th>Below Average</th>
<th>Average</th>
<th>Above Average</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Girls</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>12</td>
</tr>
</tbody>
</table>

The students were provided examination environment and they were given the tests. The time allocation, space provided for solution, student anxiety and other factors of test administration were noted. The students also highlighted their observations during an interview taken soon after test administration. Specific difficulties faced by the students were noted and discussed with them. The test was improved by removing the difficulties faced by these students.
Procedure

After final examination and result of class VIII, this experiment was started in the first week of new academic year of class IX. The prospective teachers instead of starting with first chapter of the book, taught chapter number 6 on “Concept of Matrices” of mathematics of secondary level to their groups for 40 minutes daily. The treatment continued through respective approaches for a period of three weeks.

The CBI Group

The computer based instructional approach was used to reference group-1 on the same chapter of mathematics of secondary classes. This group was furnished with computers with built-in CD Rom, multi-media and EPGY Software. Two students were given one computer and the CDs of EPGY Software. However, a single printer was connected to all computers for the use of students.

The students of this group were familiarized with the use of computer and software. For every lesson, the teacher introduced the topic for first 15 minutes and then invited the students to open the first lesson of EPGY on “Concept of Matrices”. The students started lessoning and watching using option to browse the on going screens for going back and forward in a screen. The teacher facilitated the students if they came across some specific difficulty of content and accent. The whole topic of "Concept of Matrices" was divided into 18 lessons of each 40 minutes, six days in a week (Appendix-B). Some of the lessons were reported being the lengthy sub-topics.
Each screen of instruction was followed by self-assessment questions. The students of each sub grouped got an ample opportunity to first discuss and then give responses of the problems. At some occasions students got printed the self-assessment problem for practice at home. At the end of each class, the students were given homework from the textbook and teacher checked the same in the next class.

The researcher visited this group occasionally during instructions and gave feedback for the improvement to the teachers.

**The CBL Group**

The computer based learning group was the most privileged group equipped with all possible information and communication technologies and resources. The groups were furnished with computers CD Rom, multi-media, the EPGY software and Internet connection. A single printer was connected to all computers for the use of students.

This group started learning the chapter on “Concept of Matrices” directly through EPGY Software. Whenever, the student got stacked with a problem, confused or felt need to ask some more details about a particular concept, they sent their queries and problems to the EPGY Instructor through e-mail. This instructor was representative of EPGY software developer, University of Stanford, USA and was located in Islamabad. The Instructor was already waiting for the mail of students as per schedule and he replied the student’s mails immediately. The students of this
group interacted with each other through e-mail and chatting for discussion and sharing their views on the topic.

In addition, the students got opportunities to search “Concept of Matrices” on Internet. The students got access to the lesson and material available on the topic around the world. The role of teacher in this group was of facilitator and navigator. The teachers helped students in searching material on the topic.

A live Homework help was provided to the students of CBL groups in both schools through http://www.tutor.com/. This help line service allowed the students to connect to qualified tutors up to 20-minutes live as tutoring sessions every day during break period of these groups in each school. The students got accesses to different tutors for seeking help in solving their exercises of the topic.

The student of this group used and enjoyed every possible application of information and communication technology for retrieval, manipulation and exchange of information using various resources.

**Teacher Centered Group**

The teacher-centered group represented the customary approach used in teaching of mathematics. The teacher provided instruction through lectures, focusing attention to the textbook material and to some extent the problem solving. During treatment to this group “chalk and talk” remained the most frequently used approaches of the teacher.
In addition, the teacher required students to solve some problems on their notebooks and discuss with their class-fellows. This deliberating effort to get students involved in drill and practice and interaction was considered as essential part of the treatment because the coverage of such techniques of teaching mathematics is not promoted in the textbook.

The homework was given to the students and checked regularly by the teacher. Informal feedback on teaching to students was provided by the researcher during his visits.

Test Administration

Posttest Administration

The posttest was given in each school on the same day and same time on the first school day following the completion of the three week teaching to the students of all three groups seated in a big hall. The students were given general instructions and working procedure was explained by the test administrators nominated by the Principals of each school. As the tradition of giving MCQs is not very common in our schools, therefore, the students were shown some examples of MCQs on transparencies by the test administrators before commencement of test.

The Part-I of the posttest was given to the students and was collected back after 20 minutes. Then students were then given the Part-II of the posttest. The students worked on the problems and gave solutions in the space provided under each
question. The test administrators invigilated the tests and met with students queries if they had.

Test administrators collected the copies of Part-II after one hour. The copies of Part-I and Part-II of the posttest of each student were stapled together and sealed in envelopes. The students were served with refreshment at the end from the researcher. The researcher informally chatted and discussed matters with students regarding the experiment.

Delayed posttest Administration

Four weeks subsequent to the posttest, the post-posttest (Appendix - I ) was administrated to measure student retention of the topics taught to them during treatment. This test was form of post-test whereas the sequence of MCQs and problems was changed.

The procedure, conditions and team of administration of post posttest were similar to the posttest.

Scoring of Instruments

A mathematics teacher of a Federal Government School evaluated the copies of posttest and post-posttest. The evaluator was provided the key of multiple-choice questions and the solution of problems by the researcher. The marked copies of these
tests were re-checked by another senior mathematics teacher for the purpose of objectivity and making scoring more authentic.

**Data Entry and Analysis**

The instruments were coded and entered into SPSS program for analysis. Frequencies of responses to different items under each item and questions were obtained. This helped in preparing tables for interpretation.

The data was analyzed and compared, the effect of the treatments and reference groups, ability (below average, average and above average), and gender (boys and girls) on achievement and retention scores.

Analysis of Covariance (ANCOVA) procedure from the SPSS programs was used to analyze the data. The ANCOVA Procedure was used for two reasons. First, selection and through randomization of students for the purpose of dividing them into three groups on the basis defined was not possible. Second, the use of covariant procedure mathematically controlled for the covariate (the pretest), so that the group main effect could be interpreted more easily. The ANCOVA procedure also determined two-way interactions. Post-hoc test (Tukey test) was applied on delayed-posttest for the purpose of comparison of mean score of groups. The data were therefore, readied for analysis, interpretation and drawing conclusions. The adjusted means are examined and interpreted especially where the F-test demonstrated significant relationship. Comparisons of the original (unadjusted) and adjusted group means provided insight into the role of covariates.
Chapter - IV

ANALYSIS AND INTERPRETATION OF DATA

The study was designed to investigate and compare the effect of use of information and communication technology in varied teaching approaches on achievement and retention of students of mathematics. Another purpose was to study the effect of student's ability and gender on their achievement and retention by teaching them through varied approaches.

A sample of 63 students was divided into three groups, two treatments and one reference group. First treatment group was taught mathematics topic “Concept of Matrices” of classes IX-X through computer Based instructions (CBI) and the second treatment group was provided instructions through Computer Based Learning (CBL) approach. The CBI group made use of textbook and EPGY software. The CBL in addition had opportunity of making use of all possible computer related technologies and facilities such as e-mail, chatting and internet in addition to the CBI group. The reference group was taught the same topic of mathematics through Teacher Centered (TC) approach. After four weeks period, an achievement test was administered as a posttest to all the students included in the study. The same groups were given a delayed-posttest after three weeks from the date of posttest. The copies of both tests were scored group-wise, ability-wise and sex-wise and mean of scorers were computed.

In order to respond to the research questions, the ANOCVA technique was applied using SPSS program. The data was organized in the form of tables and graphs followed by interpretations.

Significance levels of all hypothesis tested in this study were set at the 0.05 levels. The data is presented and interpreted as per research questions.
Question AR  Is there a difference of groups, ability and gender on mean score between the achievement and retention of the students' of secondary level taught mathematics through CBI, CBL and TC approaches?

Table 4

Mean Scores and Standard Deviations of Groups on Posttest and Delayed-Posttest

<table>
<thead>
<tr>
<th>Type of Test</th>
<th>CBI (N=21)</th>
<th>CBL (N=21)</th>
<th>TC (N=21)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Posttest</td>
<td>65.81</td>
<td>18.76</td>
<td>70.95</td>
</tr>
<tr>
<td>Delayed-Posttest</td>
<td>65.14</td>
<td>13.61</td>
<td>74.90</td>
</tr>
</tbody>
</table>

Figure 1.  Plot showing mean score of CBI, CBL and TC groups on Posttest and Delayed-posttest.

This figure shows that the CBL group has considerably scored higher in achieving as well as in retaining the content of mathematics taught to them during the experiment.
Table 5

*Ability-wise Mean Scores and Standard Deviations of Groups on Posttest and Delayed-Posttest*

<table>
<thead>
<tr>
<th>Type of Test</th>
<th>Below Average (N=16)</th>
<th>Average (N=20)</th>
<th>Above Average (N=27)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Posttest</td>
<td>53.69</td>
<td>19.77</td>
<td>69.80</td>
</tr>
<tr>
<td>Delayed-Posttest</td>
<td>57.00</td>
<td>20.03</td>
<td>70.70</td>
</tr>
</tbody>
</table>

Figure 2. *Plot showing mean score of below average, average and above average on Posttest and Delayed-posttest.*

This figure shows that the students of different ability levels retained the achievement of the content of mathematics taught to them during the experiment. The below average students retained the content appreciably.
Table 6

*Mean Scores and Standard Deviations of Gender of Groups on Posttest Delayed-Posttest*

<table>
<thead>
<tr>
<th>Type of Test</th>
<th>Boys (N=30)</th>
<th>Girls (N=33)</th>
<th>Total (N=63)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Posttest</td>
<td>69.43</td>
<td>18.25</td>
<td>68.15</td>
</tr>
<tr>
<td>Delayed-Posttest</td>
<td>66.13</td>
<td>18.16</td>
<td>69.94</td>
</tr>
</tbody>
</table>

*Figure 3. Plot showing mean score of gender on Posttest and Delayed-posttest*

This figure shows that the girls students overall scored appreciably higher than boys on delayed-posttest.
**Question A1** Is there a difference among the achievement of the students of secondary level taught mathematics through CBI, CBL and TC approaches?

Table 7

*Ability-wise Mean Scores and Standard Deviations of CBI, CBL and TC Groups on Posttest*

<table>
<thead>
<tr>
<th>Group</th>
<th>Below Average (N=5+6+5=16)</th>
<th>Average (N=7+6+7=20)</th>
<th>Above Average (N=9+9=9=27)</th>
<th>Marginal (N=63)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>CBI</td>
<td>52.60</td>
<td>19.59</td>
<td>61.43</td>
<td>12.51</td>
</tr>
<tr>
<td>CBL</td>
<td>52.17</td>
<td>19.06</td>
<td>77.83</td>
<td>19.36</td>
</tr>
<tr>
<td>TC</td>
<td>56.60</td>
<td>24.75</td>
<td>71.29</td>
<td>07.16</td>
</tr>
<tr>
<td>Marginal</td>
<td>53.69</td>
<td>19.77</td>
<td>69.80</td>
<td>11.87</td>
</tr>
</tbody>
</table>

An analysis of these means reveals that there is a minor difference among the marginal means for the different levels of group across the levels of ability (65.81 vs. 70.95 vs. 69.52) with standard deviations 18.76, 18.71 and 15.17 respectively. The marginal means of ability over levels of group are also different (53.69 vs. 69.80 vs. 76.93) with the mean for “below average” being the lowest (M=53.69, SD=19.77). The cell means of all three groups show an increasing pattern for levels of ability.
Table 8

Mean Scores and Standard Deviations of Gender of CBI, CBL and TC Groups on Posttest

<table>
<thead>
<tr>
<th>Group</th>
<th>Boys (N = 10+10+10=30)</th>
<th>Girls (N =11+11+11=33)</th>
<th>Marginal (N = 63)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>CBI</td>
<td>67.60</td>
<td>19.99</td>
<td>64.18</td>
</tr>
<tr>
<td>CBL</td>
<td>66.30</td>
<td>22.96</td>
<td>75.18</td>
</tr>
<tr>
<td>TC</td>
<td>74.40</td>
<td>10.24</td>
<td>65.09</td>
</tr>
<tr>
<td>Marginal</td>
<td>69.43</td>
<td>18.25</td>
<td>68.15</td>
</tr>
</tbody>
</table>

This Table shows that means of three groups for the boys and girls across marginal means are different (65.81 vs. 70.95 vs. 69.52) with the mean for “CBL” group being the highest (M=70.95, SD=18.71). The means of posttest is higher in boys of TC groups (M=74.40, SD=10.24) whereas in CBL group this means is notably higher in girls (M=75.18, SD=13.59).
### Table 9

**Analysis of Covariance Summary Table of CBI, CBL, and TC Groups on Posttest**

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sum of squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Significance of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td>4885.527</td>
<td>1</td>
<td>4885.527</td>
<td>25.604</td>
<td>.000</td>
</tr>
<tr>
<td>Main effects</td>
<td>2046.483</td>
<td>5</td>
<td>409.297</td>
<td>2.145</td>
<td>.078</td>
</tr>
<tr>
<td>Group</td>
<td>525.110</td>
<td>2</td>
<td>262.555</td>
<td>1.376</td>
<td>.263</td>
</tr>
<tr>
<td>Ability</td>
<td>1051.209</td>
<td>2</td>
<td>525.605</td>
<td>2.755</td>
<td>.075</td>
</tr>
<tr>
<td>Gender</td>
<td>798.596</td>
<td>1</td>
<td>798.596</td>
<td>4.185</td>
<td>.047*</td>
</tr>
<tr>
<td>Two-way Interactions</td>
<td>1552.338</td>
<td>8</td>
<td>194.042</td>
<td>1.017</td>
<td>.438</td>
</tr>
<tr>
<td>Group Ability</td>
<td>465.261</td>
<td>4</td>
<td>116.315</td>
<td>.610</td>
<td>.658</td>
</tr>
<tr>
<td>Group Gender</td>
<td>898.161</td>
<td>2</td>
<td>449.081</td>
<td>2.354</td>
<td>.107</td>
</tr>
<tr>
<td>Ability Gender</td>
<td>141.721</td>
<td>2</td>
<td>70.861</td>
<td>.371</td>
<td>.692</td>
</tr>
</tbody>
</table>

* Significant at .05 level

Summary Table of ANCOVA indicate no significant difference at 0.78 level among the group score of the students taught mathematics through CBI, CBL, and TC approaches. The main effects of the group (.263) and ability (.075) did not meet the .05 level of significance. However, the main effects comparison of gender was significant at 0.047, therefore meeting the 0.05 criterion level.
An examination of Table 10 shows that the 21 students of CBL groups scored considerably higher in posttest than the same numbers of students of CBI and TC groups. The students of CBL groups have an adjusted mean score of 71.10, the CBI has 64.59 and the TC group has 70.60 adjusted mean score on posttest. The ability effect shows that score of the average students is appreciably higher than below average and above average students on posttest. The 20 average students have an adjusted mean score of 73.38, below average of 16 students have 59.90 and 70.59 is an adjusted mean score of 27 above average students on posttest. In terms of gender, the boys were found to score notably higher than the girls with 30 boys having an adjusted mean score 72.76 and 33 girls having an adjusted mean score of 65.13.
Question A2  *Is there any significant interactions among the types of teaching approaches, students' ability and gender?*

The data presented in Table 9 indicates that none of the two-way interaction meets the 0.05 level of significance. The Figures 4-6, therefore shows that there is no significant interaction between groups and the ability, groups and the gender and between the ability and the gender of the students.

![Figure 4. Two-way interaction of groups and ability for posttest mean score.](image)
Figure 5. Two-way interaction of groups and gender for posttest mean score.

Figure 6. Two-way interaction of ability and gender for posttest mean score.
Is there a difference between the achievement of the students of secondary level taught mathematics through CBI and CBL approaches?

Table 11

<table>
<thead>
<tr>
<th>Group</th>
<th>Below Average (N=5+6=11)</th>
<th>Average (N=7+6=13)</th>
<th>Above Average (N=9+9=18)</th>
<th>Marginal (N=42)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>CBI</td>
<td>52.60</td>
<td>19.59</td>
<td>61.43</td>
<td>12.51</td>
</tr>
<tr>
<td>CBL</td>
<td>52.17</td>
<td>19.06</td>
<td>77.83</td>
<td>10.36</td>
</tr>
<tr>
<td>Marginal</td>
<td>52.36</td>
<td>18.31</td>
<td>69.00</td>
<td>13.98</td>
</tr>
</tbody>
</table>

An analysis of these means reveals that there is a considerable difference among the marginal means for the CBI and CBL groups across the levels of ability (65.81 vs. 70.95). The marginal means of ability over CBI and CBL groups are also different (52.36 vs. 69.00 vs. 77.72) with an increasing pattern for levels of ability. However, the marginal mean across “below average” is appreciably lower (M=52.36, SD=18.31).
Table 12

Mean Scores and Standard Deviations of Gender of CBI and CBL Groups on Posttest

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean Boys (N = 10+10=20)</th>
<th>SD</th>
<th>Mean Girls (N = 11+11=22)</th>
<th>SD</th>
<th>Mean Marginal (N = 42)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBI</td>
<td>67.60</td>
<td>19.99</td>
<td>64.18</td>
<td>18.38</td>
<td>65.81</td>
<td>18.76</td>
</tr>
<tr>
<td>CBL</td>
<td>66.30</td>
<td>22.96</td>
<td>75.18</td>
<td>13.59</td>
<td>70.95</td>
<td>18.71</td>
</tr>
<tr>
<td>Marginal</td>
<td>66.95</td>
<td>20.96</td>
<td>69.68</td>
<td>16.75</td>
<td>68.38</td>
<td>18.69</td>
</tr>
</tbody>
</table>

This Table shows that means of CBI and CBL groups for the boys and girls across the marginal means are different (65.81 vs. 70.95) with the mean for “CBL” group being the highest (M=70.95, SD=18.71). The cell mean of achievement of CBL group is notably higher in girls (M=75.18, SD=13.59).
Table 13

*Analysis of Covariance Summary Table of CBI and CBL Groups on Posttest*

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sum of squares</th>
<th>df</th>
<th>Mean square</th>
<th>F</th>
<th>Significance of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td>4544.836</td>
<td>1</td>
<td>4544.836</td>
<td>17.414</td>
<td>.000</td>
</tr>
<tr>
<td>Main effects</td>
<td>721.939</td>
<td>4</td>
<td>.692</td>
<td>.604</td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>443.767</td>
<td>1</td>
<td>443.767</td>
<td>1.700</td>
<td>.202</td>
</tr>
<tr>
<td>Ability</td>
<td>235.905</td>
<td>2</td>
<td>.452</td>
<td>.641</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>129.158</td>
<td>1</td>
<td>.495</td>
<td>.487</td>
<td></td>
</tr>
<tr>
<td>Two-way Interactions</td>
<td>998.841</td>
<td>5</td>
<td>.765</td>
<td>.582</td>
<td></td>
</tr>
<tr>
<td>Group Ability</td>
<td>213.034</td>
<td>2</td>
<td>.408</td>
<td>.669</td>
<td></td>
</tr>
<tr>
<td>Group Gender</td>
<td>261.732</td>
<td>1</td>
<td>1.003</td>
<td>.325</td>
<td></td>
</tr>
<tr>
<td>Ability Gender</td>
<td>331.437</td>
<td>2</td>
<td>.635</td>
<td>.537</td>
<td></td>
</tr>
</tbody>
</table>

Summary Table of ANCOVA for CBI and CBI groups shows that the main effects comparison between CBI and CBL groups (.604) did not meet the level of significance. Similarly, the effects of the group - ability (.669), group - gender (.325) and the ability - gender (.537) did not meet the level of significance at 0.05.
### Table 14

**Summary Table of Unadjusted and Adjusted Mean Scores of CBI and CBL Groups on Posttest**

<table>
<thead>
<tr>
<th>Type of Means</th>
<th>Group</th>
<th>Ability</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CBI (21)</td>
<td>Below Average</td>
<td>Boys (20)</td>
</tr>
<tr>
<td></td>
<td>CBL (21)</td>
<td>Average</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Above Average</td>
<td>Girls (22)</td>
</tr>
<tr>
<td>Unadjusted</td>
<td>65.81</td>
<td>52.36</td>
<td>66.95</td>
</tr>
<tr>
<td></td>
<td>70.95</td>
<td>69.00</td>
<td>69.68</td>
</tr>
<tr>
<td></td>
<td>77.72</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted</td>
<td>65.11</td>
<td>63.53</td>
<td>70.36</td>
</tr>
<tr>
<td></td>
<td>71.65</td>
<td>71.47</td>
<td>66.59</td>
</tr>
<tr>
<td></td>
<td></td>
<td>69.12</td>
<td></td>
</tr>
</tbody>
</table>

In Table 14, the data show that the students of CBL group scored higher than the students of CBI group with an adjusted mean of 71.65. The ability effect shows that score of the average students is notably higher than below average and above average students on posttest. The 14 average students have an adjusted mean score of 71.47, below average of 10 students have 63.53 and 69.12 is an adjusted mean score of 18 above average students on posttest. Similarly the boys were found to score appreciably higher than the girls with 20 boys having an adjusted mean score of 70.36 and 22 girls having an adjusted mean score of 66.59.
Question A4  Is there any significant interactions of achievement among the types of teaching approaches, CBI and CBL, students' ability and gender?

The data presented in Table 13 indicates that none of the two-way interaction meet the 0.05 level of significance. The Figures 7-9, therefore show that there is no significant interaction between groups and the ability, groups and the gender and between the abilities and the gender of the students.

Figure 7.  Two-way interaction of groups and ability for posttest mean score of CBI and CBL groups.
Figure 8. Two-way interaction of groups and gender for posttest mean score of CBI and CBL groups.

Figure 9. Two-way interaction of ability and gender for posttest mean score of CBI and CBL groups.
Question A5  Is there a difference between the achievement of the students of secondary level taught mathematics through CBI and TC approaches?

Table 15

Ability-wise Mean Scores and Standard Deviations of CBI and TC Groups on Posttest

<table>
<thead>
<tr>
<th>Group</th>
<th>Below Average (N=5=5=10)</th>
<th>Average (N=7+7=14)</th>
<th>Above Average (N=9+9=18)</th>
<th>Marginal (N=42)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>CBI</td>
<td>52.60</td>
<td>19.59</td>
<td>61.43</td>
<td>12.51</td>
</tr>
<tr>
<td>TC</td>
<td>56.60</td>
<td>24.75</td>
<td>71.29</td>
<td>07.16</td>
</tr>
<tr>
<td>Marginal</td>
<td>54.60</td>
<td>21.15</td>
<td>66.36</td>
<td>11.05</td>
</tr>
</tbody>
</table>

An analysis of these means reveals that there is a considerable difference among the marginal means for the different levels of group across the levels of ability (65.81 vs. 69.52). The marginal means of ability over levels of group are also different (54.60 vs. 66.36 vs. 75.94) with the mean for “below average” being the lowest (M=54.60, SD=21.15). The cell means of both groups show an increasing pattern for levels of ability.
Table 16

Mean Scores and Standard Deviations of Gender of CBI and TC Groups on Posttest

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>SD</th>
<th>Mean</th>
<th>SD</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys</td>
<td>67.60</td>
<td>19.99</td>
<td>64.18</td>
<td>18.38</td>
<td>65.81</td>
<td>18.76</td>
</tr>
<tr>
<td>(N = 10+10=20)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Girls</td>
<td>74.40</td>
<td>10.24</td>
<td>65.09</td>
<td>17.90</td>
<td>69.52</td>
<td>15.17</td>
</tr>
<tr>
<td>(N = 11+11=22)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marginal</td>
<td>71.00</td>
<td>15.85</td>
<td>64.64</td>
<td>17.71</td>
<td>67.67</td>
<td>16.95</td>
</tr>
<tr>
<td>(N = 42)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This Table shows that means of the CBI and TC groups for the boys and girls across the marginal means are different (65.81 vs. 69.52) with the mean for “TC” group being the highest (M=69.52, Sd=15.17). The means of achievement of posttest is higher in boys in TC (M=74.40, SD=10.24) group than in CBI group (M=67.60, SD=19.99). In both groups, the means of the girls of these groups are lower than the means of the boys.
Table 17

*Summary Table of ANCOVA indicates significant difference between the group score of the students taught mathematics through CBI and TC approaches. The combined main effects (.036) did meet the level of significance at 0.05. The main effects of group, ability and gender did not meet the level of significance at 0.05.*
An examination of Table 18 shows that 21 students of TC groups scored appreciably higher in posttest than the same numbers of students of CBI groups. The students of TC group have an adjusted mean score of 70.29 and the CBI has 65.05 adjusted mean score on posttest. The ability effect shows that score of the above average students is notably higher than below average and average students on posttest. The 18 above average students have an adjusted mean score of 71.79, below average of 10 students have 55.98 and 70.71 is an adjusted mean score of 14 average students on posttest. In terms of gender, the boys were found to score considerably higher than the girls with 20 boys having an adjusted mean score 64.64 and 21 girls having an adjusted mean score of 61.63.
Question A6  Is there any significant interactions among the CBI and TC teaching approaches, students' ability and gender?

The data presented in Table 17 indicate that no two-way interaction meet the 0.05 level of significance. The Figures 10-12, therefore shows that there is no significant interaction between groups and the ability, between group and the gender and between the ability and the gender.

![Figure 10](image.png)

*Figure 10. Two-way interaction of group and ability for posttest mean score of CBI and TC groups.*
Figure 11. Two-way interaction of groups and gender for posttest mean score of CBI and TC groups.

Figure 12. Two-way interaction of ability and gender for posttest mean score of CBI and TC groups.
Question A7  Is there a difference between the achievement of the students of secondary level taught mathematics through CBL and TC approaches?

Table 19

Ability-wise Mean Scores and Standard Deviations of CBL and TC Groups on Posttest

<table>
<thead>
<tr>
<th>Group</th>
<th>Below (N=6+5=11)</th>
<th>Average (N=6+7=13)</th>
<th>Above Average (N=9+9=18)</th>
<th>Marginal (N=42)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean  SD</td>
<td>Mean  SD</td>
<td>Mean  SD</td>
<td>Mean  SD</td>
</tr>
<tr>
<td>CBL</td>
<td>52.17 19.06</td>
<td>77.83 10.36</td>
<td>78.89 14.50</td>
<td>70.95 18.71</td>
</tr>
<tr>
<td>TC</td>
<td>56.60 24.75</td>
<td>71.29 07.16</td>
<td>75.33 09.23</td>
<td>69.52 15.17</td>
</tr>
<tr>
<td>Marginal</td>
<td>54.18 20.79</td>
<td>74.31 09.05</td>
<td>77.11 11.93</td>
<td>70.24 16.84</td>
</tr>
</tbody>
</table>

An analysis of these means reveals that there is a difference among the marginal means for the different levels of group across the levels of ability (70.95 vs. 69.52). The marginal means of ability over levels of group are also different (54.18 vs. 74.31 vs. 77.11) with the mean for "below average" being the lowest (M=54.18, SD=20.79). The cell means of all three groups show an increasing pattern for levels of ability.
Table 20

*Mean Scores and Standard Deviations of Gender of CBL and TC Groups on Posttest:

<table>
<thead>
<tr>
<th>Group</th>
<th>Boys (N = 10+10=30)</th>
<th>Girls (N = 11+11=22)</th>
<th>Marginal (N = 42)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>CBL</td>
<td>66.30</td>
<td>22.96</td>
<td>75.18</td>
</tr>
<tr>
<td>TC</td>
<td>74.40</td>
<td>10.24</td>
<td>65.09</td>
</tr>
<tr>
<td>Marginal</td>
<td>70.35</td>
<td>17.79</td>
<td>70.14</td>
</tr>
</tbody>
</table>

This Table shows that means of the CBL and TC groups for the boys and girls across the marginal means are different (70.95 vs. 69.52) with the mean for CBL group being the highest (M=70.95, SD=18.71). The means of achievement of posttest is higher in boys in TC group (M=74.40, SD=10.24) and higher in girls in CBL group (M=75.18, SD=13.59).
Table 21

*Analysis of Covariance Summary Table of CBL and TC Groups on Posttest*

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sum of squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Significance of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td>3137.757</td>
<td>1</td>
<td>3137.757</td>
<td>23.127</td>
<td>.000</td>
</tr>
<tr>
<td>Main effects</td>
<td>1479.583</td>
<td>4</td>
<td>369.896</td>
<td>2.726</td>
<td>.048*</td>
</tr>
<tr>
<td>Group</td>
<td>4.623</td>
<td>1</td>
<td>4.623</td>
<td>.034</td>
<td>.855</td>
</tr>
<tr>
<td>Ability</td>
<td>1357.584</td>
<td>2</td>
<td>678.792</td>
<td>5.003</td>
<td>.014*</td>
</tr>
<tr>
<td>Gender</td>
<td>423.665</td>
<td>1</td>
<td>423.665</td>
<td>3.123</td>
<td>.088</td>
</tr>
<tr>
<td>Two-way Interactions</td>
<td>1027.389</td>
<td>5</td>
<td>205.478</td>
<td>1.514</td>
<td>.216</td>
</tr>
<tr>
<td>Group Ability</td>
<td>28.849</td>
<td>2</td>
<td>14.425</td>
<td>.106</td>
<td>.899</td>
</tr>
<tr>
<td>Group Gender</td>
<td>863.661</td>
<td>1</td>
<td>863.661</td>
<td>6.366</td>
<td>.017*</td>
</tr>
<tr>
<td>Ability Gender</td>
<td>84.889</td>
<td>2</td>
<td>42.444</td>
<td>.313</td>
<td>.734</td>
</tr>
</tbody>
</table>

* Significant at .05 level

Summary Table of ANCOVA indicates significant difference at .048 between the group score of the students taught mathematics through CBL and Teacher Centered (TC) approaches. The main effects of the ability (.014) did meet the 0.05 level of significance. However, the main effects of the group and the gender did not meet the level of significance at 0.05.
This Table shows that the 22 students of CBL groups scored significantly higher in posttest than the same numbers of students of TC group. The students of CBL group have an adjusted mean score of 70.59 and the TC group has 69.89 adjusted mean score on posttest. The ability effect shows that score of the average students is appreciably higher than below average and above average students on posttest. The 14 average students have an adjusted mean score of 77.67, below average of 10 students have 59.90 and 70.82 is an adjusted mean score of 18 above average students on posttest. In terms of gender, the boys were found to score notably higher than the girls with 20 boys having an adjusted mean score 73.76 and 21 girls having an adjusted mean score of 67.03.
Question A8  Is there any significant interactions among the CBL and TC teaching approaches, students’ ability and gender?

The data presented in Table 21 indicate that only group and gender of the two-way interaction meet the 0.05 level of significance. The Figures 13 and 15, therefore shows that there is no significant interaction between groups and the ability and between ability and the gender. The Figure-14 shows an interaction between the groups and the gender.

![Graph showing interaction between groups and ability](image)

*Figure 13. Two-way interaction of groups and ability for posttest mean score of CBL and TC groups.*
Figure 14. Two-way interaction of groups and gender for posttest mean score of CBL and TC groups.

Figure 15. Two-way interaction of ability and gender for posttest mean score of CBL and TC groups.
Question R1 Is there a difference among the retention of the students of secondary level taught mathematics through CBI, CBL and TC approaches?

Table 23

Ability-wise Mean Scores and Standard Deviations of CBI, CBL and TC Groups on Delayed-Posttest

<table>
<thead>
<tr>
<th>Group</th>
<th>Below Average (N=5+6+5=16)</th>
<th>Average (N=7+6+7=20)</th>
<th>Above Average (N=9+9+9=27)</th>
<th>Marginal (N=63)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>CBI</td>
<td>53.40</td>
<td>13.72</td>
<td>63.14</td>
<td>08.38</td>
</tr>
<tr>
<td>CBL</td>
<td>59.83</td>
<td>18.81</td>
<td>79.33</td>
<td>13.78</td>
</tr>
<tr>
<td>TC</td>
<td>57.20</td>
<td>29.08</td>
<td>70.86</td>
<td>08.32</td>
</tr>
<tr>
<td>Marginal</td>
<td>57.00</td>
<td>20.03</td>
<td>70.70</td>
<td>11.77</td>
</tr>
</tbody>
</table>

An analysis of these means reveals that there is a difference among the marginal means for the different levels of group across the levels of ability (65.14 vs. 74.90 vs. 64.33) with standard deviations 13.61, 16.91 and 19.68 respectively on delayed-posttest. The mean of CBL group has emerged as the highest among all the groups (M=74.90, SD=16.91). The marginal means of ability over levels of group are also different (57.00 vs. 70.70 vs. 72.81) with the mean for “below average” being the lowest (M=57.00, SD=20.03). The cell means of all three groups show an increasing pattern for levels of ability.
Table 24

*Mean Scores and Standard Deviations of Gender of CBI, CBL and TC Groups on Delayed-Posttest*

<table>
<thead>
<tr>
<th>Group</th>
<th>Boys (N = 10+10+10=30)</th>
<th>Girls (N = 11+11+11=33)</th>
<th>Marginal (N = 63)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>CBI</td>
<td>65.90</td>
<td>14.90</td>
<td>64.45</td>
</tr>
<tr>
<td>CBL</td>
<td>66.90</td>
<td>19.32</td>
<td>82.18</td>
</tr>
<tr>
<td>TC</td>
<td>65.60</td>
<td>21.58</td>
<td>63.18</td>
</tr>
<tr>
<td>Marginal</td>
<td>66.13</td>
<td>18.16</td>
<td>69.94</td>
</tr>
</tbody>
</table>

This Table shows that means of three groups for the boys and girls across the marginal means are different (65.14 vs. 74.90 vs. 64.33) with the mean for "CBL" group being the highest (M=74.90, SD=16.91). The means of delayed-posttest is higher (M=82.18, SD=10.66) in girls in CBL among all groups and it is lowest (M=63.18, SD=18.76) in girls of TC group.
An examination of Table 25 reveals that the students of CBL group scored in delayed-posttest considerably higher than the same numbers (N=21) of students of CBI and TC groups. The CBL group having an adjusted means score of 75.39 whereas the CBI group with 64.95 and TC group having adjusted mean score of delayed-posttest of 64.04. In terms of ability level, the data shows that above average students appreciably scored higher than average and below average students. The 27 above average students has an adjusted mean score of 73.12 on delayed-posttest and 56.07 is of below average of 16 students and 71.03 is an adjusted mean score of 20 average students. The gender effect shows that boys were found to score higher than the girls with 30 boys having an adjusted mean score 68.31 and 33 girls having an adjusted mean score of 67.96.
## Table 26

### Analysis of Covariance Summary Table of CBI, CBL and TC Groups on Delayed Poslles/

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sum of squares</th>
<th>df</th>
<th>Mean square</th>
<th>F</th>
<th>Significance of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td>1898.628</td>
<td>1</td>
<td>1898.628</td>
<td>9.612</td>
<td>.003</td>
</tr>
<tr>
<td>Main effects</td>
<td>2462.398</td>
<td>5</td>
<td>492.480</td>
<td>2.493</td>
<td>.045*</td>
</tr>
<tr>
<td>Group</td>
<td>1628.658</td>
<td>2</td>
<td>814.329</td>
<td>4.123</td>
<td>.023*</td>
</tr>
<tr>
<td>Ability</td>
<td>1056.156</td>
<td>2</td>
<td>528.078</td>
<td>2.673</td>
<td>.080</td>
</tr>
<tr>
<td>Gender</td>
<td>1.737</td>
<td>1</td>
<td>1.737</td>
<td>.009</td>
<td>.926</td>
</tr>
<tr>
<td>Two-way Interactions</td>
<td>2151.307</td>
<td>8</td>
<td>268.913</td>
<td>1.361</td>
<td>.240</td>
</tr>
<tr>
<td>Group Ability</td>
<td>699.549</td>
<td>4</td>
<td>174.887</td>
<td>.885</td>
<td>.481</td>
</tr>
<tr>
<td>Group Gender</td>
<td>1143.914</td>
<td>2</td>
<td>571.957</td>
<td>2.896</td>
<td>.066</td>
</tr>
<tr>
<td>Ability Gender</td>
<td>198.471</td>
<td>2</td>
<td>99.236</td>
<td>.502</td>
<td>.609</td>
</tr>
</tbody>
</table>

*Significant at .05 level

Summary Table of ANCOVA indicates significant difference at the .045 level among the group retention of the students taught mathematics through CBI, CBL and Teacher Centered (TC) approaches. The main effects comparison of group was significant at 0.023, therefore meeting the 0.05 criterion level. However, the effects of the ability (.080) and the gender (.926) did not meet the level of significance at 0.05 levels.
Table 27

*Analysis of Summary Table of Multiple-Comparisons Test (Tukey HSD) of CBI, CBL and TC Groups on Delayed-Posttest*

<table>
<thead>
<tr>
<th>Comparisons</th>
<th>Means difference</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBI vs. TC</td>
<td>0.81</td>
<td>.981</td>
</tr>
<tr>
<td>CBL vs. CBI</td>
<td>9.76</td>
<td>.071</td>
</tr>
<tr>
<td>CBL vs. TC</td>
<td>10.57</td>
<td>.046*</td>
</tr>
</tbody>
</table>

Post-hoc comparison using the Tukey HSD test indicate that the means score of delayed-posttest for the CBL group (M= 74.90, SD=16.91) was significantly different from the TC group (M= 64.33, SD=19.68). The CBI group (M= 65.14, SD=13.61) did not differ significantly from either of the CBL or TC groups. However, the main effect for group (F=4.123, p=.023) reach statistical significance on delayed-posttest.
Question R2  Is there any significant interactions of retention among the types of teaching approaches, students' ability and gender?

The data presented in Table 26 indicate that none of the two-way interaction meet the 0.05 level of significance. The Figures 16-18, therefore shows that there is no significant interaction between groups and the ability, groups and the gender and between the ability and the gender of the students.

Figure 16.  Two-way interaction of group and ability for delayed-posttest mean score of CBI, CBL and TC groups.
Figure 17. Two-way interaction of group and gender for delayed-posttest mean score of CBl, CBL and TC groups.

Figure 18. Two-way interaction of ability and gender for delayed-posttest mean score of CBl, CBL and TC groups.
Question R3  Is there a difference between the retention of the students of secondary level taught mathematics through CBI and CBL approaches?

Table 28

Ability-wise Mean Scores and Standard Deviations of CBI and CBL Groups on Delayed-Posttest

<table>
<thead>
<tr>
<th>Group</th>
<th>Below Average (N=5+6=11)</th>
<th>Average (N=7+6=13)</th>
<th>Above Average (N=9+9=18)</th>
<th>Marginal (N=42)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>CBI</td>
<td>53.40</td>
<td>13.72</td>
<td>63.14</td>
<td>08.38</td>
</tr>
<tr>
<td>CBL</td>
<td>59.83</td>
<td>18.81</td>
<td>79.33</td>
<td>13.78</td>
</tr>
<tr>
<td>Marginal</td>
<td>56.91</td>
<td>16.23</td>
<td>70.62</td>
<td>13.59</td>
</tr>
</tbody>
</table>

An analysis of these means reveals that there is a significant difference among the marginal means for the CBI and CBL groups across the levels of ability (65.14 vs. 74.90). The marginal means of ability over CBI and CBL groups are different (56.90 vs. 70.62 vs. 77.61) with an increasing pattern for levels of ability. However, the marginal mean across “below average” is appreciably lower (M=56.91, SD=16.23).
Table 29

**Mean Scores and Standard Deviations of Gender of CBI and CBL Groups on Delayed-Posttest**

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>SD</th>
<th>Mean</th>
<th>SD</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys</td>
<td></td>
<td></td>
<td>Girls</td>
<td></td>
<td>Marginal</td>
<td></td>
</tr>
<tr>
<td>(N = 10+10=20)</td>
<td>(N = 11+11=22)</td>
<td>(N = 42)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CBI</td>
<td>65.90</td>
<td>14.90</td>
<td>64.45</td>
<td>13.02</td>
<td>65.14</td>
<td>13.61</td>
</tr>
<tr>
<td>CBL</td>
<td>66.90</td>
<td>19.32</td>
<td>82.18</td>
<td>10.66</td>
<td>74.90</td>
<td>16.91</td>
</tr>
<tr>
<td>Marginal</td>
<td>66.40</td>
<td>16.80</td>
<td>73.32</td>
<td>14.73</td>
<td>70.02</td>
<td>15.94</td>
</tr>
</tbody>
</table>

This Table shows that means of CBI and CBL groups for the boys and girls across the marginal means are different (65.17 vs. 74.90) with the mean for “CBL” group being the highest (M=74.90, SD=16.91). The cell mean of delayed-posttest of CBL group is appreciably higher in girls (M=82.18, SD=10.66).
Table 30

*Analysis of Covariance Summary Table of CBI and CBL Groups on Delayed-Posttest*

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sum of squares</th>
<th>df</th>
<th>Mean square</th>
<th>F</th>
<th>Significance of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td>2786.479</td>
<td>1</td>
<td>2786.479</td>
<td>17.693</td>
<td>.000</td>
</tr>
<tr>
<td>Main effects</td>
<td>1463.103</td>
<td>4</td>
<td>365.776</td>
<td>2.323</td>
<td>.080</td>
</tr>
<tr>
<td>Group</td>
<td>1173.684</td>
<td>1</td>
<td>1173.684</td>
<td>7.453</td>
<td>.011*</td>
</tr>
<tr>
<td>Ability</td>
<td>181.302</td>
<td>2</td>
<td>90.651</td>
<td>.576</td>
<td>.569</td>
</tr>
<tr>
<td>Gender</td>
<td>55.130</td>
<td>1</td>
<td>55.130</td>
<td>.350</td>
<td>.559</td>
</tr>
<tr>
<td>Two-way Interactions</td>
<td>1216.192</td>
<td>5</td>
<td>243.238</td>
<td>1.544</td>
<td>.207</td>
</tr>
<tr>
<td>Group Ability</td>
<td>32.396</td>
<td>2</td>
<td>16.198</td>
<td>.103</td>
<td>.903</td>
</tr>
<tr>
<td>Group Gender</td>
<td>624.048</td>
<td>1</td>
<td>624.048</td>
<td>3.963</td>
<td>.056</td>
</tr>
<tr>
<td>Ability Gender</td>
<td>358.414</td>
<td>2</td>
<td>179.207</td>
<td>1.138</td>
<td>.334</td>
</tr>
</tbody>
</table>

* Significant at .05 level

Summary Table of ANCOVA for CBI and CBL groups shows that the main effects comparison between CBI and CBL groups did not meet the level of significance (.080). The main effects comparison of group is significant at 0.011, therefore meeting the 0.05 criterion level. However, the effects of the ability and gender did not meet the level of significance at 0.05.
Table 31

**Summary Table of Unadjusted and Adjusted Mean Scores of Delayed-Posttest**

<table>
<thead>
<tr>
<th>Type of Means</th>
<th>Group</th>
<th>Ability</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CBI (N=21)</td>
<td>CBL (N=21)</td>
<td>Below Average (N=10)</td>
</tr>
<tr>
<td>Unadjusted</td>
<td>65.14</td>
<td>74.90</td>
<td>56.91</td>
</tr>
<tr>
<td>Adjusted</td>
<td>64.71</td>
<td>75.34</td>
<td>62.58</td>
</tr>
</tbody>
</table>

An examination of Table 31 reveals that the students of CBL group scored in delayed-posttest notably higher than the same numbers (N=21) of students of CBI group. The CBL group having an adjusted means score of 75.34 where as the CBI group with having adjusted mean score of delayed-posttest of 64.71. In terms of ability level, the data shows that adjusted mean score of above average students’ is appreciably higher than average and below average students. The 20 above average students have an adjusted mean score of 73.64 in delayed-posttest, 18 average students have 71.31 and below average of 14 students have 62.58 an adjusted mean score. The gender effect shows that girls were found to score higher than the boys with 22 girls having an adjusted mean score 71.20 and 20 boys having an adjusted mean score of 68.73.
Question R4 Is there any significant interactions of retention among the types of teaching approaches, CBI and CBL, students' ability and gender.

The data presented in Table 30 indicate that non of the two-way interaction meet the 0.05 level of significance. The Figures 19-21, therefore shows that there is no significant interaction between groups and the ability, groups and the gender and between the ability and the gender of the students.

![Graph showing two-way interaction of group and ability for delayed-posttest mean score of CBI and CBL groups.](image)

*Figure 19.* Two-way interaction of group and ability for delayed-posttest mean score of CBI and CBL groups.
Figure 20. Two-way interaction of group and gender for delayed-posttest mean score of CBI and CBL groups.

Figure 21. Two-way interaction of ability and gender for delayed-posttest score of CBI and CBL groups.
Question R5  Is there a difference between the retention of the students of secondary level taught mathematics through CBI and TC approaches?

Table 32

Ability-wise Mean Scores and Standard Deviations of CBI and TC Groups on Delayed-Posttest

<table>
<thead>
<tr>
<th>Group</th>
<th>Below Average (N=5+5=10)</th>
<th>Average (N=7+7=14)</th>
<th>Above Average (N=9+9=18)</th>
<th>Marginal (N=42)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>CBI</td>
<td>53.40</td>
<td>13.72</td>
<td>63.14</td>
<td>08.38</td>
</tr>
<tr>
<td>TC</td>
<td>57.20</td>
<td>29.08</td>
<td>70.86</td>
<td>08.32</td>
</tr>
<tr>
<td>Marginal</td>
<td>55.30</td>
<td>21.53</td>
<td>67.00</td>
<td>08.96</td>
</tr>
</tbody>
</table>

An analysis of these means reveals that there is a minor difference among the marginal means for the CBI and TC groups across the levels of ability (65.14 vs. 64.33). The marginal means of ability over levels of these groups are also different (55.30 vs. 67.00 vs. 68.22) with the mean for "below average" being the lowest (M=55.30, SD=21.53). The cell means (M=73.22, SD=12.37) of CBI group for the above average is the highest among all cell means.
Table 33

*Mean Scores and Standard Deviations of Gender of CBI and TC Groups on Delayed-Posttest*

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>SD</th>
<th>Mean</th>
<th>SD</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys</td>
<td></td>
<td></td>
<td>Girls</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(N=10+10=20)</td>
<td>65.90</td>
<td>14.90</td>
<td>64.45</td>
<td>13.02</td>
<td>65.14</td>
<td>13.61</td>
</tr>
<tr>
<td>(N=11+11=22)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CBI</td>
<td>65.60</td>
<td>21.58</td>
<td>63.18</td>
<td>18.76</td>
<td>64.33</td>
<td>19.68</td>
</tr>
<tr>
<td>TC</td>
<td>65.75</td>
<td>18.05</td>
<td>63.82</td>
<td>15.77</td>
<td>64.74</td>
<td>16.71</td>
</tr>
</tbody>
</table>

This Table shows that means of CBI and TC groups for the boys and girls across the marginal means are different (65.14 vs. 64.33). The cell means of delayed-posttest of both the groups are close to each other and as such there is no notable difference among these means.
Table 34

*Analysis of Covariance Summary Table of CBI and TC Groups on Delayed-Posttest*

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sum of squares</th>
<th>df</th>
<th>Mean square</th>
<th>F</th>
<th>Significance of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td>536.045</td>
<td>1</td>
<td>536.045</td>
<td>2.492</td>
<td>.125</td>
</tr>
<tr>
<td>Main effects</td>
<td>1064.423</td>
<td>4</td>
<td>266.106</td>
<td>1.237</td>
<td>.317</td>
</tr>
<tr>
<td>Group</td>
<td>19.370</td>
<td>1</td>
<td>19.370</td>
<td>.090</td>
<td>.766</td>
</tr>
<tr>
<td>Ability</td>
<td>945.872</td>
<td>2</td>
<td>472.936</td>
<td>2.199</td>
<td>.129</td>
</tr>
<tr>
<td>Gender</td>
<td>370.784</td>
<td>1</td>
<td>370.784</td>
<td>1.724</td>
<td>.199</td>
</tr>
<tr>
<td>Two-way Interactions</td>
<td>2307.709</td>
<td>5</td>
<td>461.542</td>
<td>2.146</td>
<td>.088</td>
</tr>
<tr>
<td>Group Ability</td>
<td>609.333</td>
<td>2</td>
<td>304.667</td>
<td>1.416</td>
<td>.259</td>
</tr>
<tr>
<td>Group Gender</td>
<td>7.809</td>
<td>1</td>
<td>7.809</td>
<td>.036</td>
<td>.850</td>
</tr>
<tr>
<td>Ability Gender</td>
<td>1638.784</td>
<td>2</td>
<td>819.392</td>
<td>3.809</td>
<td>.034*</td>
</tr>
</tbody>
</table>

* Significant at .05 level

Summary Table of ANCOVA indicates no significant difference among the group retention of the students taught mathematics through CBI and Teacher Centered (TC) approaches. The effects of the group, ability and the gender did not meet the level of significance at 0.05 levels.
**Table 35**

*Summary Table of Unadjusted and Adjusted Mean Scores of CBI And TC Groups On Delayed-Posttest*

<table>
<thead>
<tr>
<th>Type of Means</th>
<th>Group</th>
<th>Ability</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CBI (N=21)</td>
<td>TC (N=21)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Below Average (N=10)</td>
<td>Average (N=14)</td>
</tr>
<tr>
<td>Unadjusted</td>
<td>65.14</td>
<td>64.33</td>
<td>55.30</td>
</tr>
<tr>
<td>Adjusted</td>
<td>65.48</td>
<td>63.99</td>
<td>50.76</td>
</tr>
</tbody>
</table>

The data of Table 35 shows that the students of CBI group scored in delayed-posttest notably higher than the same numbers (N=21) of students of TC group. The CBI group with 65.48 and TC group having score of delayed-posttest of 63.99. In terms of ability level, the data shows that above average students appreciably scored higher than average and below average students. The 18 above average students has an adjusted mean score of 70.46 in delayed-posttest and 50.76 is of below average of 10 students and 67.37 is an adjusted mean score of 14 average students. The gender effect shows that boys were found to score higher than the girls with 20 boys having an adjusted mean score 68.13 and 22 girls having an adjusted mean score of 61.65.
**Question R6** Is there any significant interactions of retention among the types of teaching approaches CBI and TC, students' ability and gender?

The data presented in Table 34 indicate two-way interaction only between ability and gender of CBI and TC groups thus by meeting the 0.05 level of significance. The Figure 24, therefore shows significant interaction between ability and gender. The Figures 22 and 23 show no interaction between groups and the ability and between groups and the gender of the students.

![Graph](image)

**Figure 22.** Two-way interaction of group and ability for delayed-posttest mean score of CBI and TC groups.
Fig 23. Two-way interaction of group and gender for delayed-posttest mean score of CBI and TC groups.

Figure 24. Two-way interaction of ability and gender for delayed-posttest score of CBI and TC groups.
Question R7  Is there a difference between the retention of the students of secondary level taught mathematics through CBL and TC approaches?

Table 36

*Ability-Wise Mean Scores and Standard Deviations of CBL and TC Groups on Delayed-Posttest*

<table>
<thead>
<tr>
<th>Group</th>
<th>Below Average (N=6+5=11)</th>
<th>Average (N=6+7=13)</th>
<th>Above Average (N=9+9=18)</th>
<th>Marginal (N=42)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>CBL</td>
<td>59.83</td>
<td>18.81</td>
<td>79.33</td>
<td>13.78</td>
</tr>
<tr>
<td>TC</td>
<td>57.20</td>
<td>29.08</td>
<td>70.86</td>
<td>08.32</td>
</tr>
<tr>
<td>Marginal</td>
<td>58.64</td>
<td>22.74</td>
<td>74.77</td>
<td>11.53</td>
</tr>
</tbody>
</table>

An analysis of these means reveals that there is a notable difference among the marginal means for the CBL and TC groups across the levels of ability (74.90 vs. 64.33). The cell mean (M=82.00, SD=11.55) of CBL group of above average has emerged as the highest between these two groups. The marginal means of ability over levels of group are also different (58.64 vs. 74.77 vs. 72.61) with the mean (M=74.77, SD=11.53) for “average” being the highest.
<table>
<thead>
<tr>
<th>Group</th>
<th>Boys (N = 10=10=20)</th>
<th>Girls (N = 11+11=22)</th>
<th>Marginal (N = 42)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>CBL</td>
<td>66.90</td>
<td>19.32</td>
<td>82.18</td>
</tr>
<tr>
<td>TC</td>
<td>65.60</td>
<td>21.58</td>
<td>63.18</td>
</tr>
<tr>
<td>Marginal</td>
<td>66.25</td>
<td>19.95</td>
<td>72.68</td>
</tr>
</tbody>
</table>

This Table shows that means of CBL and TC groups for the boys and girls across the marginal means are different (74.90 vs. 64.33) with the mean (M=74.90, SD=16.91) for “CBL” group being the highest. The means of delayed-posttest is higher (M=82.18, SD=10.66) in girls of CBL group and it is lowest (M=63.18, SD=18.76) in girls of TC group.
Table 38

*Analysis of Covariance Summary Table of CBL and TC Groups on Delayed-Posttest*

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sum of squares</th>
<th>df</th>
<th>Mean square</th>
<th>F</th>
<th>Significance of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td>946.475</td>
<td>1</td>
<td>946.475</td>
<td>4.375</td>
<td>.045</td>
</tr>
<tr>
<td>Main effects</td>
<td>2313.761</td>
<td>4</td>
<td>578.440</td>
<td>2.674</td>
<td>.050*</td>
</tr>
<tr>
<td>Group</td>
<td>1303.832</td>
<td>1</td>
<td>1303.832</td>
<td>6.027</td>
<td>.020*</td>
</tr>
<tr>
<td>Ability</td>
<td>1095.758</td>
<td>2</td>
<td>547.879</td>
<td>2.532</td>
<td>.097</td>
</tr>
<tr>
<td>Gender</td>
<td>54.142</td>
<td>1</td>
<td>54.142</td>
<td>.250</td>
<td>.621</td>
</tr>
<tr>
<td>Two-way Interactions</td>
<td>1569.656</td>
<td>5</td>
<td>313.931</td>
<td>1.451</td>
<td>.236</td>
</tr>
<tr>
<td>Group Ability</td>
<td>235.093</td>
<td>2</td>
<td>117.547</td>
<td>.543</td>
<td>.587</td>
</tr>
<tr>
<td>Group Gender</td>
<td>956.208</td>
<td>1</td>
<td>956.208</td>
<td>4.420</td>
<td>.044*</td>
</tr>
<tr>
<td>Ability Gender</td>
<td>227.341</td>
<td>2</td>
<td>113.670</td>
<td>.525</td>
<td>.597</td>
</tr>
</tbody>
</table>

* Significant at .05 level

Summary Table of ANCOVA indicates considerable difference among the group retention of the students taught mathematics through CBL and TC approaches. The main effects did meet the 0.05 level of significance (0.050). The main effects comparison of group was also significant at 0.020, therefore meeting the 0.05 criterion level. However, the effects of the ability and the gender did not meet the level of significance at 0.05 levels.
### Summary Table of Unadjusted and Adjusted Mean Scores of CBL and TC on Delayed-Posttest

<table>
<thead>
<tr>
<th>Type of Means</th>
<th>Group</th>
<th>Ability</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CBL (N=21)</td>
<td>TC (N=21)</td>
<td>Below Average (N=10)</td>
</tr>
<tr>
<td>Unadjusted</td>
<td>74.90</td>
<td>64.33</td>
<td>58.64</td>
</tr>
<tr>
<td>Adjusted</td>
<td>75.55</td>
<td>63.69</td>
<td>56.43</td>
</tr>
</tbody>
</table>

An examination of Table 35 reveals that the students of CBL group scored in delayed-posttest appreciably higher than the same numbers (N=21) of students of TC group. The CBL group having an adjusted means score of 75.55 whereas the TC group having scores 63.69 on delayed-posttest. In terms of ability level, the data shows that above average students scored higher than average and below average students. The 18 above average students have an adjusted mean score of 74.37 in delayed-posttest and 56.43 is of below average of 10 students and 74.20 is an adjusted mean score of 14 average students. The gender effect shows that girls were found to score higher than the boys with 22 girls having an adjusted mean score 70.76 and 22 girls having an adjusted mean score of 68.36.
Question R8  Is there any significant interactions of retention among the types of teaching approaches CBL and TC, students ability and gender?

The data presented in Table 38 indicate that two-way interaction of group and gender meets the 0.05 level of significance. However, no two-way interaction exists between group and ability and ability and gender. The Figures 26, therefore, shows that there is a significant interaction between group and gender. The figures 25 and 27 shows no interaction between group and the ability and between the ability and the gender of the students.

![Graph showing interaction between group and ability](image)

**Figure 25.** Two-way interaction of group and ability for delayed-posttest mean score of CBL and TC groups.
Figure 26. Two-way interaction of group and gender for delayed-posttest mean score of CBL and TC groups.

Figure 27. Two-way interaction of ability and gender for delayed-posttest mean score of CBL and TC groups.
SUMMARY, FINDINGS, CONCLUSION, DISCUSSION AND RECOMMENDATIONS

Summary

The present study was designed to study the effects of use of Information and Communication Technology in Computer-Based Instruction, Computer-Based Learning and traditional Teacher Centered approaches on achievement and retention of students of mathematics in Pakistan. The following were the objectives of the study:

1. To compare the effects of use of information and communication technology using CBI, CBL and TC approaches on achievement of students of mathematics.
2. To compare the effects of use of information and communication technology using CBI, CBL and TC approaches on retention of students of mathematics.
3. To find out more effective approach of teaching mathematics from CBI, CBL and TC approaches to the secondary schools students.

The research questions were established as under:

1. Is there a difference on mean score among the achievement and retention of the students of secondary level taught mathematics through CBI, CBL and TC approaches?
2. Is there a difference among the achievement of the students of secondary level taught mathematics through CBI, CBL and TC approaches?

3. Is there any significant interactions (of achievement) among the types of teaching approaches (CBI, CBL and TC), students’ ability (below average, average and above average) and gender (boys and girls)?

4. Is there a difference among the achievement of the students of secondary level taught mathematics through CBI and CBL approaches?

5. Is there any significant interactions (of achievement) among the types of teaching approaches (CBI and CBL), student’s ability (below average, average and above average) and gender (boys and girls)?

6. Is there a difference among the achievement of the students of secondary level taught mathematics through CBI and TC approaches?

7. Is there any significant interactions (of achievement) among the types of teaching approaches (CBI and TC), student’s ability (below average, average and above average) and gender (boys and girls)?

8. Is there a difference among the achievement of the students of secondary level taught mathematics through CBL and TC approaches?

9. Is there any significant interactions (of achievement) among the types of teaching approaches (CBL and TC), student’s ability (below average, average and above average) and gender (boys and girls)?

10. Is there a difference among the retention of the students of secondary level taught mathematics through CBI, CBL and TC approaches?
11. Is there any significant interactions (of retention) among the types of teaching approaches (CBI, CBL and TC), student’s ability (below average, average and above average) and gender (boys and girls)?

12. Is there a difference among the retention of the students of secondary level taught mathematics through CBI and CBL approaches?

13. Is there any significant interactions (of retention) among the types of teaching approaches (CBI and CBL), student’s ability (below average, average and above average) and gender (boys and girls)?

14. Is there a difference among the retention of the students of secondary level taught mathematics through CBI and TC approaches?

15. Is there any significant interactions (of retention) among the types of teaching approaches (CBI and TC), student’s ability (below average, average and above average) and gender (boys and girls)?

16. Is there a difference among the retention of the students of secondary level taught mathematics through CBL and TC approaches?

17. Is there any significant interactions (of retention) among the types of teaching approaches (CBL and TC), student’s ability (below average, average and above average) and gender (boys and girls)?

The Posttest-Only Control Group Design was adapted for this study. Two instruments were used for the collection of data required to answer the research questions. These were Posttest and the delayed-posttest. The Posttest instrument was developed to measure the achievement of students of all three groups on the topic.
taught to them during the study. The delayed-posttest was developed for the purpose of measuring the retention of the topic taught to the students of all groups. This test was form of posttest and a table of random numbers was used to randomize the sequence of the questions of the posttest (achievement) and delayed-posttest (retention). Changing the sequence of questions and the time interval between administrations of the two tests reduced the sensitization to the instrument. Both the tests were gone through the process of development, revision, validation and try-out.

The computer based instructional approach was used to reference group-I in the same chapter of mathematics of secondary classes. These groups were furnished with text book, computers with built-in CD Rom, multi-media and EPGY Software. The whole topic of “Concept of Matrices” was divided into 18 lessons of each 40 minutes, six days in a week. The students of each sub group got an ample opportunity to discuss, interact and use the software. At the end of each class, the students were given homework from the textbook and teachers checked the same in the next class.

The students of computer based learning groups (reference group -2) were furnished with all possible information and communication technologies and resources. The groups were provided, the textbook, computers, CD Rom, multi-media, the EPGY software and Internet connection. This group started learning the chapter on “Concept of Matrices” directly through EPGY Software. Whenever, the student got stacked with a problem, confused or felt need to ask some more details about a particular concept, they sent their queries and problems to the EPGY Instructor through e-mail. This instructor was representative of EPGY software developer, University of Stanford, USA and was located in Islamabad. The students
of these groups interacted with each other through e-mail and chatted for discussion and sharing their views on the topic. The students got opportunities to search “Concept of Matrices” on Internet. The students got access to the lesson and material available on the topic around the world. The role of teacher in this group was of facilitator and navigator. The teachers helped students in searching material on the topic. A live Homework help was provided to the students of CBL groups in both schools through http://www.tutor.com/. This help line service allowed the students to connect to qualified tutors up to 20-minutes live as tutoring sessions every day during break period of these groups in each school. The students got accesses to different tutors for seeking help in solving their exercises of the topic. The student of this group used and enjoyed every possible application of information and communication for retrieval, manipulation and exchange of information using various resources.

The teacher-centered groups represented the customary approach used in teaching of mathematics. The teachers of these groups provided instruction through lectures, focusing attention to the textbook material and to some extent the problem solving. During treatment to this group “chalk and talk” remained the most frequently used approaches of the teacher. The teacher required students to solve some problems on their notebooks and discuss with their class-fellows. This deliberating effort to get students involves in drill and practice and interaction was considered as essential part of the treatment because the coverage of such techniques of teaching mathematics is not promoted in the textbook. The homework was given to the students and checked regularly by the teachers.
The posttest was given in each school on the same day at the same time on the first school day following the completion of the three week teaching to the students of all three groups seated in a big hall. The students were given general instructions and working procedure was explained by the test administrators nominated by the Principals of each school. The Part-I of the posttest was given to the students and was collected back after 20 minutes. Then students were then given the Part-II of the posttest. The students worked on the problems and gave solutions in the space provided under each question. The test administrators invigilated the tests and met with students’ queries if they had. Test administrators collected the copies of Part-II after one hour. The copies of Part-I and Part-II of the posttest of each student were stapled together and sealed in envelopes.

Four weeks subsequent to the posttest, the delayed-posttest was administrated to measure student retention of the topics taught to them during treatment. This test was form of post-test whereas the sequence of MCQs and problems was changed. The procedure, conditions and team of administration of delayed-posttest were similar to the posttest.

A mathematics teacher evaluated the copies of posttest and delayed-posttest. The evaluator was provided the key of multiple-choice questions and the solution of problems by the researcher. The marked copies of these tests were re-checked by another senior mathematics teacher for the purpose of objectivity and making scoring more authentic. The instruments were coded and a statistical program was used for analysis. Frequencies of responses to different items under each item and questions were obtained. This helped in preparing tables for interpretation.

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The data was analyzed and compared the effect of the treatments and reference groups, ability (below average, average and above average), and gender (boys and girls) on achievement and retention scores. Two-way analysis of Covariance (ANCOVA) procedure from SPSS program was used to analyze the data. The ANCOVA procedure also determined two-way interactions. Post-hoc comparison of mean scores was applied on delayed-posttest score using the Tukey, HSD test for difference of means between the groups.

Findings

The findings of research questions of the present study were as follows:

1. There was a trivial difference among the marginal means for different levels of group across the levels of ability on posttest. The marginal means of ability over levels of group were also different with the mean for “below average” being the lowest. The cell means of all three groups showed an increasing pattern for levels of ability.

2. The means posttest of three groups for the boys and girls across marginal means were different with the mean for “CBL” group being the highest. The means of achievement of posttest was higher in boys in CBI and TC groups whereas in CBL group this means was considerably higher in girls.

3. The adjusted mean of CBL group was considerably higher in posttest than CBI and TC groups. The ability effect showed that adjusted mean of the average students was considerably higher than below average and above average students. The adjusted mean of boys was appreciably higher than the girls.
4. There was a momentous difference among the marginal means for the CBI and CBL groups across the levels of ability on posttest. The marginal means of ability over CBI and CBL groups were also different with an increasing pattern for levels of ability. However, the marginal mean across “below average” was appreciably lower.

5. The means of CBI and CBL groups for the boys and girls across the marginal means were different with the mean for “CBL” group being the highest. The cell mean of achievement of CBL group was considerably higher in girls.

6. The adjusted mean of CBL group was higher than the students of CBI group in posttest. The ability effect showed that adjusted mean of the average students was considerably higher than below average and above average students. The adjusted mean of boys was notably higher than the girls.

7. There was a noteworthy difference among the marginal means for the different levels of groups CBI and TC across the levels of ability on posttest. The marginal means of ability over levels of group were also different with the mean for “below average” being the lowest. The cell means of both groups showed an increasing pattern for levels of ability.

8. The means of the CBI and TC groups for the boys and girls across the marginal means were different with the mean for “TC” group being the highest. The means of achievement of posttest was higher in boys in TC group than in CBI. In both groups, the means of the girls of these groups were lower than the means of the boys student.

9. The adjusted mean of TC group scored appreciably higher in posttest than the same numbers of students of CBI group. The ability effect showed that adjusted mean
of the above average students was considerably higher than below average and average students on posttest. The adjusted mean of boys was considerably higher than the girls.

10. There was a momentous difference among the marginal means for the different levels of CBL and TC groups across the levels of ability on posttest. The marginal means of ability over levels of group were also different with the mean for "below average" being the lowest. The cell means of both groups showed an increasing pattern for levels of ability.

11. The means of the CBL and TC groups for the boys and girls across the marginal means were different with the mean for "CBL" group being the highest. The means of achievement of posttest was higher in boys in TC group and higher in girls in CBI group.

12. The adjusted mean of CBL group was radically higher in posttest than TC group. The ability effect showed the adjusted mean of average students was notably higher than below average and above average students on posttest. The adjusted mean of boys was appreciably higher than the girls.

13. There was a considerable difference among the marginal means of the delayed posttest for the different levels of group across the levels of ability. The mean of CBL group had emerged as the highest among all the groups. The marginal means of ability over levels of group were also different with the mean for "below average" being the lowest. The cell means of all three groups showed an increasing pattern for levels of ability.

14. Post-hoc comparison using the Tukey HSD test indicate that the means score of delayed-posttest for the CBL group was significantly different from the TC group.
The CHI group did not differ significantly from either of the CBL or TC groups. However, the main effect for group reach statistical significance on delayed-posttest. The means of three groups for the boys and girls across the marginal means were different with the mean for “CBL” group being the highest on delayed-posttest. The means of delayed-posttest was higher in girls in CBL among all groups and it was lowest in girls of TC group.

The adjusted mean of CBL group scored in post-posttest was considerably higher than the same numbers of students of CBI and TC groups. The ability effect showed that the adjusted mean of above average students was appreciably higher than average and below average students. The gender effect showed that the adjusted mean of boys was higher than the girls.

There was a notable difference among the marginal means for the CBI and CBL groups across the levels of ability on delayed-posttest. The marginal means of ability over CBI and CBL groups were different with an increasing pattern for levels of ability. The marginal mean across “below average” was considerably lower.

The means of CBI and CBL groups for the boys and girls across the marginal means were different with the mean for “CBL” group being the highest. The cell mean of delayed-posttest of CBL group was considerably higher in girls.

The adjusted mean of CBL group in delayed-posttest was considerably higher than CBI group. In terms of ability level, the adjusted mean of above average students was notably higher than average and below average students. The adjusted mean of girls was higher than the boys.

There was a notable difference among the marginal means for the CBI and TC groups across the levels of ability on delayed-posttest. The marginal means of ability
over levels of these groups were also different with the mean for “below average” being the lowest. The cell means of CBI group for the above average was the highest among all cell means.

21. The means of CBI and TC groups for the boys and girls across the marginal means were different. The cell means of delayed-posttest of both the groups were close to each other and as such there was no major difference among these means.

22. The adjusted mean of CBI group in post-posttest was appreciably higher than TC group. The adjusted mean of above average students was appreciably higher than average and below average students. The gender effect showed that the adjusted mean of boys was higher than the girls.

23. There was an appreciably difference among the marginal means for the CBL and TC groups across the levels of ability on delayed-posttest. The mean of CBL group had emerged as the highest between these two groups. The marginal means of ability over levels of group were also different with the mean for “average” being the highest.

24. The means of CBL and TC groups for the boys and girls across the marginal means were different with the mean for “CBL” group being the highest. The means of delayed-posttest was higher in girls of CBL group and it was lowest in girls of TC group.

25. The adjusted mean of CBL group in delayed-posttest was considerably higher than TC group. The adjusted mean of above average students was higher than average and below average students. The gender effect showed that adjusted mean of girls was higher than the boys.
Conclusion

1. There was no significant difference among the group score of the students taught mathematics through CBI, CBL and Teacher Centered (TC) approaches on achievement. The main effects of the group and ability did not meet the 0.05 level of significance. However, the main effects comparison of gender was significant at 0.047, therefore meeting the 0.05 criterion level.

2. There was no significant interaction between groups and the ability, groups and the gender, between the abilities and the gender of the students of all three groups on achievement.

3. The main effects comparison between CBI and CBL groups did not meet the level of significance on achievement. The effects of the group, ability and the gender did not meet the level of significance.

4. There was no significant interaction between groups and the ability, groups and the gender, between the abilities and the gender of the students of CBI and CBL groups on achievement.

5. There was a significant difference between the group score of the students taught mathematics through CBI and Teacher Centered (TC) approaches on achievement. The combined main effects did meet the level of significance. The main effects of group, ability and gender did not meet the level of significance.

6. There was no significant interaction between groups and the ability, between groups and the gender, between the ability and the gender of students of CBI and TC groups on achievement.
7. There was a significant difference between the group score of the students taught mathematics through CBL and TC approaches on achievement. The main effects of the ability did meet the level of significance. The main effects of the group and the gender did not meet the level of significance.

8. There was no significant interaction between CBL and TC groups and the ability, between ability and the gender on achievement. There was an interaction between the groups and the gender.

9. There was a significant difference among the group retention of the students taught mathematics through CBI, CBL and Teacher Centered (TC) approaches. The main effects of the ability did meet the level of significance. The main effects comparison of group was also significant, therefore meeting the criterion level.

10. There was no significant interaction between the groups and the ability, groups and the gender, between the abilities and the gender of the students of all three groups on retention.

11. The means score of delayed-posttest for the CBL group was significantly different from the TC group. The CBI group did not differ significantly from either of the CBL or TC groups. However, the main effect for group reached statistical significance on delayed-posttest.

12. The main effects comparison between CBI and CBL groups did not meet the level of significance on delayed posttest. The main effects comparison of groups was significant, therefore meeting the criterion level. The effects of the group, ability and gender did not meet the level of significance.
13. There was no significant interaction between CBI and CBL groups and the ability, groups and the gender, between the abilities and the gender of the students on retention.

14. There was no significant difference among the group retention of the students taught mathematics through CBI and Teacher Centered (TC) approaches. The effects of the groups, ability and the gender did not meet the level of significance.

15. There was two-way interaction between ability and gender of CBI and TC groups by meeting the level of significance on retention. There was a significant interaction between ability and gender. Also there was no interaction between groups and the ability and between groups and the gender of the students.

16. There was a significant difference among the group retention of the students taught mathematics through CBL and Teacher Centered (TC) approaches. The main effects did meet the level of significance. The main effects comparison of group was also significant, therefore meeting the criterion level. The effects of the ability and the gender did not meet the level of significance.

17. There was a two-way interaction of CBL and TC groups and gender meeting the level of significance. However, no two-way interaction exists between group and ability and ability and gender. There was a significant interaction between groups and gender. There was no interaction between groups and the ability and between the ability and the gender of the students.

18. The CBL group has appreciably scored higher in achieving as well as in retaining the content of mathematics taught to them during the experiment. The below average students retained significantly the achievement of the content of mathematics
taught to them during the experiment. The girls students overall scored considerably higher than the boys in delayed posttest.

Discussion

The present study was undertaken to compare the effects of use of information and communication technology in CBI, CBL and TC approaches on achievement and retention of students of mathematics in Pakistan. The effectiveness of a more appropriate approach of teaching of mathematics to the students of Pakistan at secondary level was also investigated. The findings from the achievement instrument (Posttest) indicated no significant differences between the reference and control groups. However, while comparing the achievement of CBI and TC groups, the TC group performed better than the CBI group. Similarly, by comparing the CBL and TC groups, the CBL group performed better than the TC group on achievement test. The findings from the retention instrument (delayed-Posttest) showed a significant difference between the reference and control groups. The CBL group performed better than the CBI and TC groups in delayed-Posttest meaning that the students retained the learned matter of mathematics for a long time if they are taught the subject of mathematics through CBL approach. These results are robust when viewed in light of CBI, CBL and TC approaches reported in almost similar kind of studies.

The results on achievement test of this study reinforce evidence of Clark (1983, 1984) that media do not influence learning, but merely provide access. According to Clark (1985), gains in achievement are attributable to the instructional
method and content rather than the method or mode of delivery. The use of CBI and CBL approaches as reference group while comparing with the Teacher Centered (TC) approach in this study supported the research carried out by Carrier et al., (1985) where he concluded that “placing a child in a situation which has a high level of instructionally – relevant content does not mean that he or she will afford to or use this information productively”. The significant achievement of TC group over the CBI group in this study is also identical to a study conducted by Randall et al., (1995) in the subject of secondary school mathematics where he found that better achievement gains in the students of traditional teaching than the students of computer-based instruction may be due to the fact that the commercial software used did not cover all the concepts and was the culture oriented. Similarly, it can be noted that the use of EPGY software in typical Pakistani situation had some practical difficulties of implementation.

The significant achievement of CBL group over TC group came up in identical to many studies in which CBL approach appears to have a rather consists positive effect an achievement. Many reviewers found increases in achievement from 0.27 to 0.56 standard deviation for computer-based technologies when compared with traditional approaches (Pisapia & Perlman, 1992).

Some researchers have demonstrated differently. Meta-analysis conducted by Kulik and Kulik (1980,1984, 1987, 1991) summarized the findings of 248 controlled evaluation studies of technology – mediated learning. In 81% of these studies, students in technology-mediated studies achieved a higher mean examination score than students in traditionally taught classes. Although Kulik and Kulik reported
positive effects of computer related instruction in their meta-analysis of a large body of research, the statistical power of using multiple studies is compromised in the confounding of variables. Computer Based Instruction itself represents many different forms as new technologies emerge. These new technologies and media are rarely distinguished from the instructional design and content they deliver as pointed out by Clark. Clark (1985) examined the confounding of CBI effects in Kulik's meta-analysis demonstrating serious problems in construct validity in CBI studies. When CBI modes are compared with traditional delivery, a confounding of medium and method often occurs. Because instructional methods are imbedded in CBI treatments, traditional treatments need to contain equivalent instructional methods to isolate the effects of CBI (Clark, 1985). Modes of delivery, including computer-based technology, are "mere media that may be vehicle of instruction but should not to be confused with instruction itself" (Clark 1994).

A study entitled "Classroom Instruction Differences by Level of Technology used in Mathematics" was conducted by Waxman and Hung (1996). The results of this study indicated that there were significant differences in classroom instruction by the amount of technology used. Instruction in classroom settings where technology was not often used tended to be whole-class approaches where students generally listened or watched the teacher. Instruction in classroom settings where technology was moderately used had much less whole-class instruction and much more independent work. These findings are quite similar to the researches that support the notion that technology use may change teaching from the traditional teacher centered model to a more student-centered instructional approach.
A study on effectiveness of computer program “Fundamentally Math” has revealed that the students who utilized the computer software scored significantly higher than the students who did not participated at a 99.5% confidence level. The algebra students using the software made 17% jump in scores (Brown, 2000). Another study on the effect of CBI on students was published by Abbas Johari (1998). Johari subjects were students of pre-calculus class. He had one CBI and the other traditional lecture group. The group that received the computer based instructions scored significantly higher on the posttest. The researchers concluded that relationship exists between the use of a computer based instruction and achievement of students of mathematics.

In a study by Augustine (2000), on effectiveness of teaching mathematics online, the researcher has used the computer based learning approach and compared with the achievement of student exposed through traditional methods. The researchers found that there was a significant difference on achievement of both groups. The CBI group scored higher significantly. The findings of Augustine’s study support the results of present study where the CBI group scored significantly higher than the TC group on achievement test.

According to Fouts (2000), in a later review of research of online technologies, Bracewell, et. al., (1998) attempted to find studies that examined learning outcomes, but minimal success. They found only a “few small scale studies” and agreed with the 1998 UNESCO World Report that there were few studies that showed that school online usage demonstrated clear learning gains over conventional classroom processes.
The present study showed significant difference on retention between the reference (CBI and CBL) and control (TC) groups meaning that instruction imparted through CBI and CBL approaches are retained by the learners for a long time as compared to TC group. This result indicates that the learning though use of information technology (CBI and CBL) has long lasting effects. Although there was no significant difference among these groups on achievement but the same groups have came up with significant difference among which the CBL is the highest one when measured after four weeks period. The result of the study shows that the use of information and communication technology has longer effects on retention which is the ultimately objective of teaching of mathematics as indicated by Tahir (2001).

The effects on retention are generally positive, but not as clear as initial achievement because retention is difficult to exactly measure. Five studies with follow up examinations investigated retention over intervals ranging from 2 to 6 months were reviewed by Pisapia & Perlman (1993). In four of these studies, retention examination scores were higher in the CBI class, but in none of these four retention effects were large enough to be considered statistically significant. In the remaining study, retention examination scores were significantly higher in the control group.

The findings of the present study also indicate that the below average students retained more than the average and above average students. This finding is consistent with some other studies that appeared in the literature on similar kind of situation. These studies show that the effect of computer-based teaching seemed especially clear in studies of disadvantaged and low aptitude students; for example, effect
appeared too much smaller in studies of talented students (Bangert-Drown et al., 1985; Burns & Bozeman 1981 each cited in Pisapia & Perlman, 1992, and; Niemiec & Walberg, 1988; Robyler et al., 1988; Oslon & Krendl, 1990). Research on the effect with at-risk student learning is promising. These students often show significant gains in achievement levels in basic content area (Oslon & Krendl, 1990).

In Pakistani context, it may be speculated that most of the below average students belongs to lower socioeconomic status and they do not have access to the information and communication technologies. Therefore, when these students gets opportunity to computer and related technologies, they take it quite serious and get involve thus by retaining the learnt matter for a long time as compared to the other students who do not take the ICT seriously.

The results of the present study indicate that girls overall scored considerably higher than the boys in delayed-posttest. Unfortunately, no research literature is available in favour or against the finding of this study. Perhaps, the reason is that most of such studies are carried out in developed countries where gender bias is almost eliminated. The Boards results indicated that girls in our society are comparatively better than boys in study generally (BISE, 2002). Also, it is observed that Pakistani girls' look more interested in use and application of computers and related technologies. Perhaps, this can be a reason for retaining the learnt matter of mathematics by Pakistani girls as compared to the boys in this study.

The literature provides support as well as goes against the performance of students in the subject of mathematics by use of information and communication technology depending on level, the topic, the software and the approach. In a report
on Research on Computer and Education: Past, Present and Future prepared by Bill and Melinda Gates Foundation, Fouts (2000) expressed that in a national study sponsored by Educational Testing Service, Does it compute? The Relationship Between Educational Technology and Student Achievement in Mathematics (Wenglinsky, 1998), the researcher found that "technology could matter, but that this depended upon how it was used" (p. 3). Teachers' professional development in technology and using the technology to teach higher order thinking skills were both related to academic achievement, but the overall frequency of school computer use was negatively related to academic achievement. These and other equivocal findings suggest that there are a number of other factors that interact with the technology. Wenglinsky concluded:

All of this suggests that computers are neither cure-all for the problems facing schools, nor mere fads that have no impact on student learning. Rather, when they are properly used, computers may serve as important tools for improving student proficiency in mathematics, as well as the overall learning environment in the school. (p. 4).

Research on school restructuring in Washington State (Fouts, 1999) found that between 1993 and 1997 an increase in the use of technology was the most common classroom change reported by elementary teachers. However, there was no relationship found between the reported increases in technology used and achievement gains on standardized tests of basic skills. However, unlike in the ACOT studies, there were no indications that the technology was used for that specific purpose.
In a study by Roberts and Stephens (1999), the group not utilizing the software in geometry scored higher than those who used software in learning of geometry. These results indicate that using computer software may not be beneficial when teaching certain topics in the subject of mathematics. A study by Clarniana (1997) on effects on an Integrated Learning System (ILS) on the mathematics test scores of elementary school children indicates that ILS software had its greatest effect on mathematics concepts scores. In a comparative study by Schumacher, Young and Bembry (1995) on mathematics attitudes and achievement of Algebra I students, the researchers compared the achievement of students taught mathematics through computer software (CBI) and through traditional teachers lecture methods. The traditional lecture group in the average scored higher than the computer-assisted group in mathematics. Again, the researchers are of the view that this might have been because the commercial software used did not cover all the concepts.

Once again it is important to note that proponents of information and communication technology argue that the purpose of the technology is not to produce higher test scores, but rather to increase "other" types of learning, which are the focus of current school reform efforts. For example, a recent ERIC Digest report (Kosakowski, 1998) stated: "Most available tests do not reliably measure the outcomes being sought... Assessments of the impact of technology are really assessments of the instructional processes enabled by technology, and the outcomes are highly dependent on the quality of the implementation of the entire instructional process." Consequently, many technology proponents are not overly concerned about the relationship between the technology and the standardized test scores.
Since the 1970s, many research studies have been conducted on the effect of computers in the schools. One category of studies included those reviewed by Kulik (Kulik, Bangert, & Williams, 1983; Kulik, Kulik, & Bangert Drowns, 1984, 1985; Kulik, Kulik, & Cohen, 1980). These studies essentially compared two groups of students with each other. One group received CBI while the other group received comparable instruction by some other method, usually live teaching. Certainly, this kind of research is interesting and could be important if it were possible to demonstrate that computers were a consistently better delivery system than other media. Unfortunately, this kind of "bottom line" research is controversial, and while studies such as Kulik's have produced generalize-able result, some conclusions from this research are considered suspect.

There also has been a shift in how computers are used that has not been adequately tested by researchers. Increasingly, educators are designing computer environments where learners interact with instructional events. Students are allowed to construct their learning activities based on their own interpretation of what is needed. They are not presented with information; rather they are expected to interact and even cause changes to the information made available by the computer based system.

To the end of this discussion, it can be concluded that current mathematics reforms has encouraged the use of computers in learning and teaching mathematics. Recent researches also provide strong evidence of the usefulness of computers in mathematics learning. However, it can be safely committed that goal of the studies like the present study is to make room for experimental researches on a particular
field of study and practices, likewise the use of information and communication technology in instruction of mathematics. The President's Committee (Fouts, 1999) of USA stated that the principal goal of such empirical works should not be to answer the question of whether computers can be effectively used within the schools. The research, therefore must be seen as a concerted effort to answer the broadest research question – "How information and communication technology is used in teaching of mathematics" – rather than should information and communication technology be used in teaching the subject of mathematics"? Or whether information and communication technology affected the achievement gains of the students in a particular subject”?

**Recommendations**

Having gone through an intensive research work on effect of use of information and communication technology on achievement and retention of students of secondary schools in Pakistan, the researcher is able to make the following recommendations.

1. A national survey on availability, utilization and skills of teachers of mathematics and science in computer related technologies should be carried out for proper planning, training and using information technology in classroom teaching.
2. The computer software may be developed locally, covering all the topics of mathematics according to the new mathematics curriculum of year 2000.
3. A model of teacher training on use of information and communication technology need to be developed for effective instruction of mathematics and other science subjects.

4. Some specific concepts and topics may be identified through try-out and researches that can be taught better and effectively through the use of information and communication technology on typical situation of Pakistan.

5. The use of information and communication technology needs to be integrated in all the subjects and specifically in the subject of mathematics at secondary level. For this purpose, an appropriate adjustment and room may be made in the scheme of studies and in the school time table.

6. The below average students of mathematics need to be given supplementary coaching through use of information and communication technology for the purpose of reinforcement.

7. Some experimental and empirical studies may be carried out in Pakistani situation to answer the questions likewise: Do students from poorer families and lower socio-economic background demonstrate higher or lower levels of motivations toward learning information and communication technology? What is effect of information and communication technology rich classrooms and teaching on at-risk students (the below average students)? What is the effect of information and communication technology rich classrooms and teaching on gifted students? Does creating an information and communication technology rich mathematics learning environment handicap some students? At what grade or age level is it appropriate to use information and communication technology in teaching of mathematics? How
information and communication technology can be best used in teaching of mathematics? Is instruction through use of information and communication technology helpful in imparting basic skills and concepts of mathematics? How much time and access to information and communication technology does a student need to affect learning? What type of computers and related technologies skills are required for the students of mathematics at secondary level? How can information and communication technology be best used to provide immediate feedback on student learning?
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Appendix - A

Program of the Experiment (April-May, 2002)

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Activity</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Orientation and Training of Teachers</td>
<td>One Week</td>
</tr>
<tr>
<td>2.</td>
<td>Orientation of CBI and CBL Groups’ Students</td>
<td>One Week</td>
</tr>
<tr>
<td>3.</td>
<td>Experiment (Teaching)</td>
<td>Three weeks regular teaching</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(18 periods)</td>
</tr>
<tr>
<td>4.</td>
<td>Post Test Administration</td>
<td>80 minutes</td>
</tr>
<tr>
<td>5.</td>
<td>Delayed-Posttest Administration</td>
<td>80 minutes</td>
</tr>
</tbody>
</table>
**Appendix – B**

*Time Table of the Experiment*

<table>
<thead>
<tr>
<th>Day</th>
<th>Main Topic</th>
<th>Period No.</th>
<th>Sub-Topics</th>
</tr>
</thead>
</table>
| 1.  | Matrix and Order of a matrix | I          | Introduction  
 |     |             |            | Rows and Column of a matrix  |
| 2.  | Types of a matrix | II         | Row matrix, Column matrix, square matrix, Rectangular matrix, Zero matrix  
<p>|     |             |            | Exercises and SAQs  |
| 3.  | Operations of Matrices | III        | Addition of matrices  |
| 4.  |             | IV         | Subtraction of matrices  |
| 5.  | Operations of Matrices | V          | Additive Inverse of a matrix  |
| 6.  |             | VI         | Multiplication of a number by a real number  |
| 7.  | Operations of Matrices | VII       | Exercises and SAQs  |
| 8.  |             | VIII       | Exercises and SAQs  |
| 9.  | Multiplication of Matrices | IX        | Multiplication of Matrices  |
| 10. |             | X          | Multiplication of Matrices continued  |
| 11. | Determinants and Some other types of Matrices | XI        | Determinants of a matrix, Singular matrix, Non-Singular matrix  |
| 12. |             | XII        | Diagonal matrix, Unit matrix, Adjoint of a matrix, multipartite inverse of a matrix  |
| 13. | Determinants and Some other types of Matrices | XIII      | Exercises and SAQs  |
| 14. |             | XIV        | Exercises and SAQs  |
| 15. | Solution of Simultaneous Linear Equations | XV        | Introduction to the topic and steps of finding solution of simultaneous equations  |
| 16. |             | XVI        | Examples  |</p>
<table>
<thead>
<tr>
<th></th>
<th>17. Solution of Simultaneous Linear Equations</th>
<th>XVII Exercises and SAQs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18. Linear Equations</td>
<td>XVIII Exercises and SAQs</td>
</tr>
</tbody>
</table>

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Appendix – C

Program of Orientation and Training of Teachers

<table>
<thead>
<tr>
<th>Day</th>
<th>Activity</th>
<th>Participants</th>
</tr>
</thead>
</table>
| I   | • Introduction  
    • Briefing about study  
    • Aims and Objectives of study  
    • Methodology and Procedure of the experiment  
    • Tasks of teachers  
    • Do’s and Don’ts for teachers of different groups | All six teachers belonging to CBI, CBL and TCA groups |
| II  | • Introduction to EPGY software  
    • Demonstration of EPGY  
    • Loading of software  
    • Starting, selecting, browsing and existing from the software | Four teachers belonging to CBI and CBL groups |
| III | • Watching software related to the topic  
    • Taking notes of key points of software  
    • Solving Self-assessment questions  
    • Hands on software | Four teachers belonging to CBI and CBL groups |
| IV  | • Using of Websites  
    • Recognizing different internet resources of mathematics around the world  
    • Identifying some important resources of teaching of mathematics on internet | Two teachers belonging to CBL groups |
| V   | • Use of e-mail  
    • Signing up for e-mail  
    • Use and method of chatting  
    • Checking, composing and sending an e-mail and an attachment with e-mail  
    • Typing mathematical assignments and questions by making use of Program “Mathtype” on MS office | Two teachers belonging to CBL groups |
| VI  | • Using live homework help on http://www.tutor.com/ | |
• Connecting and making appointment with tutor
• Using and practicing the Screen board of the live homework site
• Hands on internet

Two teachers belonging to CBL groups
## Program of Orientation of Students Belonging to CBI and CBL Groups

<table>
<thead>
<tr>
<th>Day</th>
<th>Activity</th>
</tr>
</thead>
</table>
| I   | • Introduction to computer  
    | • Organization of simple digital computer system  
    | • Memory, RAM and CPU  
    | • Introduction to the Peripheral Devices – Input devices, Output devices and Secondary memory |
| II  | • Getting starting on PC  
    | • Introduction to MS Office  
    | • Tour to Windows of MS Office |
| III | • Composing, saving, copying, cutting, pasting, editing and retrieving a document on MS Office  
    | • Hands on MS Office |
| IV  | • Using of Websites  
    | • Recognizing different internet resources of mathematics around the world  
    | • Identifying some important resources of teaching of mathematics on internet |
| V   | • Use of e-mail  
    | • Signing up for e-mail  
    | • Use and method of chatting  
    | • Checking, composing and sending an e-mail and an attachment with e-mail  
    | • Typing mathematical assignments and questions by making use of Programme “Mathype” on MS office |
    | • Connecting and making appointment with tutor  
    | • Using and practicing the Screen board of the live homework site  
    | • Hands on internet |
### Appendix – E

**Group Formation CBI Group**

<table>
<thead>
<tr>
<th>Ability Level</th>
<th>Coding Nos. of the Students (from 1 to 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below Average</td>
<td>4, 8, 1, 9</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>2, 7</td>
</tr>
<tr>
<td>Above Average</td>
<td>3, 10, 6, 5</td>
</tr>
</tbody>
</table>

**Boys**

**Girls**

<table>
<thead>
<tr>
<th>Ability level</th>
<th>Coding Nos. of the Students (from 11 to 21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below Average</td>
<td>15</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>20, 18, 12, 16, 11</td>
</tr>
<tr>
<td>Above Average</td>
<td>17, 13, 14, 19, 21</td>
</tr>
</tbody>
</table>
Formation of CBL Group

**Boys**

<table>
<thead>
<tr>
<th>Ability level</th>
<th>Coding Nos. of the Students (from 22 to 31)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below Average</td>
<td>29, 27, 24, 30</td>
</tr>
<tr>
<td>Average</td>
<td>31, 23</td>
</tr>
<tr>
<td>Above Average</td>
<td>22, 28, 26, 25</td>
</tr>
</tbody>
</table>

**Girls**

<table>
<thead>
<tr>
<th>Ability level</th>
<th>Coding Nos. of the Students (from 32 to 42)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below Average</td>
<td>34</td>
</tr>
<tr>
<td>Average</td>
<td>38, 33, 40, 42, 37</td>
</tr>
<tr>
<td>Above Average</td>
<td>39, 32, 35, 41, 36</td>
</tr>
</tbody>
</table>
### TC Group

#### Boys

<table>
<thead>
<tr>
<th>Ability level</th>
<th>Coding Nos. of the Students (43 to 52)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below Average</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>51</td>
</tr>
<tr>
<td>Average</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>47</td>
</tr>
<tr>
<td>Above Average</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>49</td>
</tr>
</tbody>
</table>

#### Girls

<table>
<thead>
<tr>
<th>Ability level</th>
<th>Coding Nos. of the Students (53 to 63)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below Average</td>
<td>57</td>
</tr>
<tr>
<td>Average</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>63</td>
</tr>
<tr>
<td>Above Average</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>62</td>
</tr>
<tr>
<td></td>
<td>58</td>
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</table>
Appendix – F

*Table of Random Numbers for Posttest and Delayed-Posttest*

### Part - I

<table>
<thead>
<tr>
<th>Type of Test</th>
<th>MCQ No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posttest</td>
<td>1  2  3  4  5  6  7  8  9  10  11  12  13  14  15</td>
</tr>
<tr>
<td>Delayed-posttest</td>
<td>7  9  10  5  1  2  11  3  14  6  8  15  12  4  13</td>
</tr>
</tbody>
</table>

### Part - II

<table>
<thead>
<tr>
<th>Type of Test</th>
<th>Q.NO.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posttest</td>
<td>1  2  3  4  5  6</td>
</tr>
<tr>
<td>Delayed-posttest</td>
<td>3  5  2  1  6  4</td>
</tr>
</tbody>
</table>

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Appendix - G

Posttest

Mathematics
Topic: Concept of Matrices

Name: ____________________________

School/College: ____________________________

Group( TCA/CBI/CBL): _______

Boy/Girl: _______

Instructions:

- This test has two parts. Part A is comprised of Multiple Choice Questions (MCQs) which will be collected after 20 minutes.

- In Part-B, you are required to give complete solution of the problems in one hour in the space provided.

- Please see the solved example carefully and start working on MCQs when you are asked.

- Please follow the instructions of Examination Supervisors.
PART - A

Time: 20 Minutes
Marks: 15

Instruction:

Given below four options for each of the statement of the question. Please choose the correct response and mark (✓) on the left side of the correct option as described in the example given below:

Solved Example:

A Zero matrix has

_____ a. no element
_____ b. one zero element
_____ c. all zero elements
✓ d. zero elements in diagonal
_____ e. c and d

STOP

START WHEN ASKED
1. A Zero matrix can be

   ____ a. square matrix
   ____ b. rectangular matrix
   ____ c. row matrix
   ____ d. column matrix
   ____ e. any one of the above type of matrix

2. The order of matrix \[
\begin{bmatrix}
0 \\
0
\end{bmatrix}
\] is

   ____ a. 0x0
   ____ b. 1x1
   ____ c. 2x1
   ____ d. 1x2
   ____ e. 2x2

3. Two equal matrices have same

   ____ a. corresponding entries
   ____ b. rows and columns
   ____ c. non-zero columns
   ____ d. a and b
   ____ e. b and c

4. The matrix \([3]\) is a

   ____ a. rectangular matrix
   ____ b. square matrix
   ____ c. Identity matrix
   ____ d. zero matrix
   ____ e. all of the above
5. The matrix \[
\begin{bmatrix}
1 & 0 \\
0 & 1
\end{bmatrix}
\] is a
   ___ a. diagonal matrix
   ___ b. identity matrix
   ___ c. zero matrix
   ___ d. rectangular matrix
   ___ e. none of the above

6. The matrix \[
\begin{bmatrix}
3 \\
2
\end{bmatrix}
\] is a
   ___ a. row matrix
   ___ b. diagonal matrix
   ___ c. square matrix
   ___ d. rectangular matrix
   ___ e. none of the above

7. Two matrices of order 2x2 and 3x2 can not be
   ___ a. added
   ___ b. subtracted
   ___ c. multiplied
   ___ d. b and c
   ___ e. a, b and c

8. The matrices \[
\begin{bmatrix}
2 & -1 \\
3 & 2
\end{bmatrix}
\] and \[
\begin{bmatrix}
4 \\
0
\end{bmatrix}
\] can be
   ___ a. added
   ___ b. subtracted
   ___ c. multiplied
   ___ d. a and b
   ___ e. b and c
9. For any two matrices $A$ and $B$ of order 2x2 each, which of the following operation is not possible in general

   ___ a. $A + B$
   ___ b. $A - B$
   ___ c. $2A + 3B$
   ___ d. $AB$
   ___ e. $AB = BA$

10. Two matrices $A$ and $B$ are multiplicative inverse of each other if

   ___ a. $AB = I$
   ___ b. $BA = I$
   ___ c. $AB = BA \neq I$
   ___ d. $AB = BA \neq I$
   ___ e. none of the above

11. For a matrix $A$ to have a multiplicative inverse, it should be

   ___ a. singular
   ___ b. non-singular
   ___ c. unit matrix
   ___ d. zero matrix
   ___ e. diagonal matrix
12. Additive inverse of matrix \( A = \begin{bmatrix} 2 & 3 \\ -1 & 5 \end{bmatrix} \) is

   - a. \( \begin{bmatrix} -2 & 3 \\ 1 & 5 \end{bmatrix} \)
   - b. \( \begin{bmatrix} 2 & -3 \\ -1 & -5 \end{bmatrix} \)
   - c. \( \begin{bmatrix} -2 & 3 \\ 1 & 5 \end{bmatrix} \)
   - d. \( \begin{bmatrix} -2 & -3 \\ 1 & -5 \end{bmatrix} \)
   - e. \( \begin{bmatrix} -2 & 3 \\ -1 & -5 \end{bmatrix} \)

13. For a matrix \( A = \begin{bmatrix} 4 & 7 \\ -3 & 2 \end{bmatrix} \), \( |A| \) is equal to

   - a. 13
   - b. -13
   - c. 29
   - d. -29
   - e. none of the above

14. If \( \begin{bmatrix} -3 & -5 \\ 3 & x \end{bmatrix} \) is a singular matrix then the value of \( x \) is

   - a. 5
   - b. -5
   - c. 3
   - d. -3
   - e. none of the above
15. For the equation $3x - 7y = 5$, the matrix form is

- a. $\begin{bmatrix} 3 \\ -7 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = 5$
- b. $\begin{bmatrix} x \\ y \end{bmatrix} \begin{bmatrix} 3 \\ -7 \end{bmatrix} = 5$
- c. $\begin{bmatrix} 3 \\ -7 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = 5$
- d. $\begin{bmatrix} 3 \\ -7 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = 5$
- e. $\begin{bmatrix} 3 \\ -7 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = 5$
**PART - B**

Time: 1 Hour

Marks: 35

**Instructions:**

i) Solve the questions in the space given below each question.

ii) Perform each of the following matrix operations wherever possible.

1. \[
\begin{bmatrix}
3 & 4 \\
5 & 7 
\end{bmatrix}
- \begin{bmatrix}
3 & 2 \\
9 & 4 
\end{bmatrix}
= \]

2. \[
\begin{bmatrix}
2 & 4 \\
5 & 7 
\end{bmatrix}
\times \begin{bmatrix}
3 & 4 \\
-3 & 5 
\end{bmatrix}
= \]
3. If \( A = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}, \quad B = \begin{bmatrix} -3 & -2 \\ 1 & -5 \end{bmatrix} \) and \( C = \begin{bmatrix} -2 & 0 \\ 4 & -1 \end{bmatrix} \) then show that \( A + B - C = 0 \) 

4. If \( A = \begin{bmatrix} 2 & 0 \\ -1 & 1 \end{bmatrix}, \quad B = \begin{bmatrix} 0 & 1 \\ 3 & 2 \end{bmatrix} \) and \( C = \begin{bmatrix} 1 & 3 \\ 2 & 4 \end{bmatrix} \) then find the value of \( 2A^2 - BC \)
5. If \( A = \begin{bmatrix} 3 & 10 \\ -2 & 6 \end{bmatrix} \) (10)

Find \( A^{-1} \) and show that \( AA^{-1} = 1 \)
6. Solve the following system of equations with the help of matrices

\[ \begin{align*}
2x + 6y &= 28 \\
4x - 3y &= -19
\end{align*} \]
Delayed - Posttest

Mathematics

Topic: Concept of Matrices

Name: _______________________________

School/College: _______________________________

Group (TCA/CBI/CBL): __________

Boy/Girl: __________

Instructions:

• This test has two parts, Part A is comprised of Multiple Choice Questions (MCQs) which will be collected after 20 minutes.

• In Part-B, you are required to give complete solution of the problems in one hour in the space provided.

• Please see the solved example carefully and start working on MCQs when you are asked.

• Please follow the instructions of Examination Supervisors.
PART - A

Time: 20 Minutes

Marks: 15

Instruction:

Given below four options for each of the statement of the question. Please choose the correct response and mark (✓) on the left side of the correct option as described in the example given below:

Solved Example:

A Zero matrix has

___ a. no element
___ b. one zero element
___ c. all zero elements
✓✓ d. zero elements in diagonal
___ e. c and d

STOP

START WHEN ASKED
1. The matrix \[
\begin{bmatrix}
1 & 0 \\
0 & 1
\end{bmatrix}
\] is a
   ____ a. diagonal matrix
   ____ b. identity matrix
   ____ c. zero matrix
   ____ d. rectangular matrix
   ____ e. none of the above

2. The matrix \[
\begin{bmatrix}
3 \\
2
\end{bmatrix}
\] is a
   ____ a. row matrix
   ____ b. diagonal matrix
   ____ c. square matrix
   ____ d. rectangular matrix
   ____ e. none of the above

3. The matrices \[
\begin{bmatrix}
2 & -1 \\
3 & 2
\end{bmatrix}
\] and \[
\begin{bmatrix}
4 \\
6
\end{bmatrix}
\] can be
   ____ a. added
   ____ b. subtracted
   ____ c. multiplied
   ____ d. a and b
   ____ e. b and c

4. If \[
\begin{bmatrix}
-3 & -5 \\
3 & x
\end{bmatrix}
\] is a singular matrix then the value of x is
   ____ a. 5
   ____ b. -5
   ____ c. 3
   ____ d. -3
   ____ e. none of the above
5. The matrix $[3]$ is a
   ___ a. rectangular matrix
   ___ b. square matrix
   ___ c. Identity matrix
   ___ d. zero matrix
   ___ e. all of the above

6. Two matrices $A$ and $B$ are multiplicative inverse of each other if
   ___ a. $AB=I$
   ___ b. $BA=I$
   ___ c. $AB=BA=I$
   ___ d. $AB=BA\neq I$
   ___ e. none of the above

7. A Zero matrix can be
   ___ a. square matrix
   ___ b. rectangular matrix
   ___ c. row matrix
   ___ d. column matrix
   ___ e. any one of the above type of matrix

8. For a matrix $A$ to have a multiplicative inverse, it should be
   ___ a. singular
   ___ b. non-singular
   ___ c. unit matrix
   ___ d. zero matrix
   ___ e. diagonal matrix
9. The order of matrix \[ \begin{bmatrix} 0 \\ 0 \end{bmatrix} \] is

___ a. 0x0
___ b. 1x1
___ c. 2x1
___ d. 1x2
___ e. 2x2

10. Two equal matrices have same

___ a. corresponding entries
___ b. rows and columns
___ c. non-zero columns
___ d. a and b
___ e. b and c

11. Two matrices of order 2x2 and 3x2 can not be

___ a. added
___ b. subtracted
___ c. multiplied
___ d. b and c
___ e. a, b and c

12. For a matrix \( A = \begin{bmatrix} 4 \\ 3 \\ 7 \\ 2 \end{bmatrix} \), \( |A| \) is equal to

___ a. 13
___ b. -13
___ c. 29
___ d. -29
___ e. none of the above
13. For the equation $3x-7y=5$, the matrix form is

- a. $\begin{bmatrix} 3 \\ -7 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = 5$
- b. $\begin{bmatrix} x \\ y \end{bmatrix} \begin{bmatrix} 3 \\ -7 \end{bmatrix} = 5$
- c. $\begin{bmatrix} 3 \\ -7 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = 5$
- d. $\begin{bmatrix} 3 \\ -7 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = 5$
- e. $\begin{bmatrix} 3 \\ -7 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = 5$

14. For any two matrices $A$ and $B$ of order $2 \times 2$ each, which of the following operations is not possible in general?

- a. $A + B$
- b. $A - B$
- c. $2A + 3B$
- d. $AB$
- e. $AB = BA$
15. Additive inverse of matrix \( A = \begin{bmatrix} 2 & 3 \\ -1 & 5 \end{bmatrix} \) is

--- a. \( \begin{bmatrix} -2 & 3 \\ 1 & 5 \end{bmatrix} \)

--- b. \( \begin{bmatrix} 2 & -3 \\ -1 & -5 \end{bmatrix} \)

--- c. \( \begin{bmatrix} -2 & 3 \\ 1 & 5 \end{bmatrix} \)

--- d. \( \begin{bmatrix} -2 & -3 \\ 1 & -5 \end{bmatrix} \)

--- e. \( \begin{bmatrix} -2 & 3 \\ -1 & -5 \end{bmatrix} \)
PART - B

Instructions:

iii) Solve the questions in the space given below each question.
iv) Perform each of the following matrix operations wherever possible.

1. If \( A = \begin{bmatrix} 2 & 0 \\ -1 & 1 \end{bmatrix} \), \( B = \begin{bmatrix} 0 & 1 \\ 3 & 2 \end{bmatrix} \), \( C = \begin{bmatrix} 1 & 3 \\ -2 & 4 \end{bmatrix} \) (6)

Find the value of \( 2A^2-BC \)
2. If \( A = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix} \), \( B = \begin{bmatrix} -3 & -2 \\ 1 & -5 \end{bmatrix} \) and \( C = \begin{bmatrix} -2 & 0 \\ 4 & -1 \end{bmatrix} \)

then show that \( A + B - C = 0 \)

3. \( \begin{bmatrix} 3 & 4 \\ 5 & 7 \end{bmatrix} - \begin{bmatrix} 3 & 2 \\ 9 & 4 \end{bmatrix} = \)

\( \)
4. Solve the following system of equations with the help of matrices

\[
\begin{align*}
2x + 6y &= 28 \\
4x - 3y &= -19
\end{align*}
\]
5. \[
\begin{bmatrix}
2 & 4 \\
5 & 7 
\end{bmatrix} \times \begin{bmatrix}
3 & 4 \\
-3 & 5 
\end{bmatrix} =
\]

(4)
6. If \( A = \begin{bmatrix} 3 & 10 \\ -2 & 6 \end{bmatrix} \) (10)

Find \( A^{-1} \) and show that \( AA^{-1} = 1 \)