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A COMPARATIVE ANALYSIS OF STUDENT PERFORMANCE
UTILIZING COMPUTER BASED INSTRUCTION AND
TEACHER BASED INSTRUCTION WITHIN A
SECONDARY MATHEMATICS SETTING

A Project
Presented to the
Faculty of
California State University,
San Bernardino

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts
in
Education:
Instructional Technology

by
John Douglas Sawtelle

December 2002

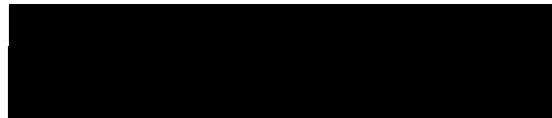
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ABSTRACT

This project addresses the question: does computer based instruction enhance student learning when compared to traditional lecture or teacher based instruction?

The overall purpose of this project was an assessment of student performance before and after using computer based instruction versus a before and after assessment using traditional teacher based instruction. It was a limited study within a limited physical, temporal and student-teacher population.

A review of the current literature suggests that computer based instruction generally improves test scores. However, the findings of this study were different. Teacher based instruction and computer based instruction were both found to improve test scores but teacher based instruction was found to be more wide-ranging and equally as beneficial as computer based instruction.

ACKNOWLEDGEMENTS

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Secondly, I wish to thank my peers for their guidance, influence, and help.

I also wish to acknowledge all the educators who throughout my life have encouraged me to explore my capabilities and retain my curiosity.

Lastly, I wish to thank the American ancestry for providing me a country wherein I have the opportunity to pursue an education of my choosing.

DEDICATION

I dedicate this work to Karin J. Hanson, without whose patient support my ideas would never materialize.

Seest thou a man wise in his own conceit? There is more hope of a fool than of him.

Proverbs 26:12

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CHAPTER ONE

PROJECT BACKGROUND

Introduction

In 1983, it was brought squarely to the national attention that a "rising tide of mediocrity" permeated our schools (United States Department of Education [USDE], 1983). An era of education reform began. Since 1997, California has adopted legislation aimed at improving our student performance through a massive infusion of technology.

The question as to whether technology can and does, in and of itself, solve student performance issues is fundamental to this project.

Context of the Problem

In 1997, the California State Legislature determined that "Traditional learning is enhanced by appropriate technology" (California Education Code [CED], 1997). A desire to improve student achievement guided that legislation, but it lacked a comprehensive, specific vision of what students specifically need to enhance their education.

This addition to the Educational Code initiated significant funding into the California educational system through various programs. One prominent program is titled

the Digital High School Program. This program supports a rapid and extensive computer acquisition scheme requiring that every public school classroom be connected to the Internet within four years, and furthermore that technology be integrated into the curriculum at the same time (California Education Code [CEC], 2000).

The ongoing focus of education across all disciplines and grade levels within California's primary and secondary public school system is the expanding use of computers as a primary and adjunct teaching device. Much of this activity is driven by two concomitant events: a legitimate public concern that our students are not performing at an academic level expected of them (Markham, 1993) and the availability of significant legislative funding for equipment and teacher training through numerous programs (CEC, 2000).

Given that educational technologies are currently receiving significant attention, questions are now being raised regarding the research and assessment results that support the adoption and inclusion of technology in all levels of the educational system, particularly because the investments have been and remain so high (Jones & Paolucci, 1999). Increasing numbers of post-secondary institutions

require students to possess laptops, raising expectations that the computer will play an important role in instruction (Cabilio & Farrell, 2001).

A presumption leading this technological focus is a legislative belief in technology as an immediate and trustworthy remedy concerning perceived poor student performance. A modest amount of objective evidence has surfaced to sustain this belief, but not enough to justify the large expenditures currently being experienced (Jones & Paolucci, 1999). However, this technological solution seems well entrenched. Much like a charging elephant, it has not carefully considered its direction and path.

Today, many objective observers on this issue are beginning to realize that the research supporting the massive adoption of technology simply does not exist. Questions arise as to the efficacy of computer based instruction. Is student performance enhanced when compared to traditional lecture based instruction? Can technology solve the perceived problem of poor classroom student performance? Is our technology at a point where it can service our educational needs, and what are those specific needs?

Educators are unable to clearly know whether the legislature's rush to judgment is correct. That is reasonable in that we cannot know the impact of an action until we assess the action. Consequently, the educational industry has elected to capitalize on the legislative financial windfall by making considerable technological acquisitions.

This is a significant change to the educational landscape. When any significant change occurs in a child's education, educators can reasonably expect to find some positive as well as negative impacts. Technology as a participant in education is a significant change and educators cannot really know with any certainty the outcome of this pedagogical shift.

Prior to 1999 no specific or subject content standards of student performance existed in the State of California. In 1997, the California State Board of Education adopted academic performance standards based upon recommendations from the Academic Standards Commission. In 1999, the Board adopted and published discipline specific content standards (California State Board of Education [CDE], 2002).

These standards occurred about the same time as legislation supporting technological acquisition. Since technol-

ogy and standards must exist side-by-side then it is reasonable to expect a confluence of direction and goals. Applying the adopted standards to a non-technical situation becomes somewhat moot.

Prior to the adoption of state standards high school diplomas came to signify the completion of course requirements based upon local planning efforts to improve a school's efficiency and effectiveness. Because there was no statewide academic performance standard to measure student academic performance then it follows that there is no objective way with which to compare student academic performance before and after the wide-scale introduction of technology into the classroom. Consequently, any analysis of the impact of computers becomes a post implementation study based upon assumptions and judgments, albeit experientially based and probably reliable.

Purpose of the Project

This project essentially addresses the question: is student performance enhanced using Computer Based Instruction (CBI) when compared to traditional lecture or Teacher Based Instruction (TBI)?

As discussed above, an existing statewide performance standard prior to the recent emergence of technology in the classroom was not in place. Coachella Valley High School, however, had a situation whereby a before and after analysis of the impact of technology became available. As required by this project, the use of technology and its impact on performance could be studied. This approach is narrowed due to being only a local situation.

During the year 2002, Coachella Valley High School installed throughout the campus a variety of technological equipment, including an abundance of computers allocated to the school through state funding. This was a significant event in that computers and technology did not exist on the campus in prior years; all academic classrooms consisted only of blackboards, textbooks and teachers. Any technology present at all, was the personal property of the faculty or the administration.

Most classrooms suddenly had computers where none existed before. Curriculum changes and subject instruction through technology was targeted to commence immediately and concurrently with any technology skills acquisition by both students and faculty. This sudden transition provided an

opportunity to assess student performance before and after a strong technology acquisition, and within a short time-frame. This project exploited the limited educational technology base of both faculty and students as it relates to performance before the introduction of technology.

Significance of the Project

This project addresses a gap in the comparison of education before technology and education after technology. As pointed out before, there is no database with which to assess the impact of the current technology based education when compared to the impact of a non-technologically based education.

Although limited in scope this project provides a measurement in an isolated environment unaffected by technology. The relative freedom from contamination of the test subjects by the global incursion of technology afforded the investigator an opportunity to experience the transition with the students as they moved from a non-technology to a full technology. Such an opportunity is probably unusual and certainly unlikely in the future.

Assumptions

The Glencoe Publication Mathematics Test Bank Generator program was provided to all secondary mathematics teachers using Glencoe mathematics textbooks. This computer program was the source of the pretest and posttest of this project. The computer program supports the California Department of Education approved Glencoe Publishing suite of High School Mathematics textbooks (1998 edition). Test validity is thereby presumed satisfactory. See Appendix A for examples of the test bank.

Limitations

This project was conducted once. Project reliability could be established if a similar project were conducted in a comparable fashion and had the same results.

Students and teacher had a working knowledge of each other. The teacher knew how best to communicate with the students and likewise the students knew how to affectively communicate with the teacher. This could introduce a Rosenthal effect whereby the project finds what it is looking for.

The project execution was isolated from other researchers. It had no experience with the advantage of ad-

vice and counsel by other professional educators, not withstanding the available literature.

Definition of Terms

The following terms have a particular meaning within this project.

Computer Based Instruction (CBI): Any instruction utilized or reviewed in this project that is conducted by a computer simulating traditional classroom lecture techniques for lesson and concept instruction. Students interact by replaying the instruction and reviewing examples.

Teacher Based Instruction (TBI): Any instruction utilized or reviewed in this project that is conducted by a teacher using traditional classroom lecture techniques for lesson and concept instruction. Students typically interact by asking questions and reviewing examples.

Organization of the Thesis

This thesis is divided into four chapters: background, literature, methodology, and recommendations.

Chapter one discusses the entire project: the initiating problem, the project purpose and scope, any perceived limitations and assumptions, and any unique definitions. Chapter Two reviews pertinent and current public and schol-

arly literature about similar research projects or discussions. The literature is categorized into three groups: contemporary research, computer based instruction and assessment, and meta-cognitive analyses. Chapter Three discusses the conduct and findings of the project. This includes development of the project, treatment and instruments, resource allocation, testing, and the statistical results. Chapter Four presents conclusions and recommendations inferred by the project.

CHAPTER TWO
REVIEW OF THE LITERATURE

Introduction

The available contemporary literature is rife with a variety of computer based instruction studies. However, regarding the focus of this project, a comparison of Computer Based Instruction (CBI) and Teacher Based Instruction (TBI), the literature is scarce and few documents include peer review. A careful reading of those source documents lacking peer review suggest many are prepared responsibly and can be considered as reliable documents. The following review of the literature is not limited to strictly scholarly or peer-reviewed publications and does therefore include other appropriate documents, where they appear reliable.

The literature generally groups into three logical categories: contemporary research, computer based instruction and assessment, and meta-cognitive analyses. The distribution of available source documents was found to be disproportionate among the three categories and is similarly allocated in this review. Consequently, the computer based instruction and assessment category contains many

references whereas the contemporary research category contains few references.

The order of category presentation reflects the relevance of the category to the project, with the following categorical discussion being most relevant.

Contemporary Research

Very few contemporary or recent scholarly or peer reviewed basic research studies, comparable to this research project, are represented in the available documentation. This probably reflects a concern about the worth of such research since a ubiquitous commitment to technology in education is firmly established. In addition, basic research conducted with much earlier generations of computer systems - usually more than five years old - are not comparable with today's needs or technology and were therefore ignored.

Most research is designed and conducted within very specific and narrow definitions. Likewise, the research documentation is very narrow and restricted as to its inquiry and its conclusion. Only two peer reviewed research studies similar to this study were considered relevant: Owens, 1994; and McKethan, 2001.

The Owens research study compared the relative effectiveness of CBI and TBI for teaching a developmental education mathematics course to African-American post-secondary students. An analysis of covariance revealed a statistically significant difference, favoring students in the CBI section on the Geometry posttest. Yet there was no significant difference on the Algebra posttest. At the end of the course, students in the CBI section had significantly higher attitudes toward mathematics than students in the TBI sections. There were no differential effects of CBI for males and females. Males, however, had significantly higher scores on the Geometry and Algebra posttest and higher attitudes toward mathematics at the end of the course than female students (Owens & Waxman, 1994). The results of the study indicate that CBI is effective for teaching developmental mathematics courses in geometry. On the other hand, the results indicate that CBI may not be effective for teaching algebra. This differential may be explained as a figure-based course compared to an abstract-based course. Another important factor considered in this study was how CBI affects student's attitude towards mathematics. The study found significant and meaningful attitudinal differ-

ences between students in the CBI and TBI groups. Follow-up descriptive or ethnographic studies that focus on some plausible explanations of why student attitudes dramatically increased were recommended.

The McKethan research study examined the effects of a multimedia/CBI strategy and TBI on teaching cognitive components of manipulative skills to physical education majors in a university setting. Subjects were randomly assigned to a control group, a multimedia group or a lecture group. The multimedia group received instruction on components of the overhand throw, catch and kick using a multimedia computer program while the lecture group received instruction via the traditional lecture method. The control group received no instruction on the selected skills. All subjects completed a pretest and posttest. ANOVA analysis with repeated measures indicated that significant differences existed between groups on a test of components and cue descriptors of manipulative skills. A series of one-way ANOVA analysis indicated that differences in scores existed between groups (McKethan & Everhart, 2001). The significance of those differences appears subjective. A shortfall in this study is the small size of the sample population, 44 students in

total. A simplified calculation of the margin of error exceeds .25 producing questionable results. It is unclear why the study used a non-participating control group. Since TBI was already in place prior to the study then the TBI group would be the control group. The value of this research is its lack of any significant finding. This suggests the question regarding the value of CBI over TBI is more complex than a simple yes or no, and especially within this particular course of study.

A relevant study lacking peer review was conducted at Northridge University. An experimental design was conducted wherein 33 students in a statistics course were randomly divided into two groups, one taught in a traditional classroom style and the other taught virtually on the World Wide Web. Text, lectures and exams were standardized between the two conditions. Contrary to hypotheses, quantitative results demonstrated that the virtual class scored an average of 20% higher than the traditional class on both examinations. Furthermore, post-test results indicate the virtual class had significantly higher perceived peer contact and time spent on class work than did the traditional class (Schutte, 1996).

Computer Based Instruction and Assessment

Computer Based Instruction and Computer Based Assessment have evolved into a viable option for teachers. However, it seems that teachers do not use computers as a real part of a pedagogical strategy but only as an added tool to their teaching. Additionally, there has been little research carried out globally thus far to support the claims about the learning and teaching benefits of computers (Baillie & Percoco, 2000). Yet computers are efficient tools for delivering instructional content, and their use is especially growing in the area of assessing student achievement. Computerized testing is desirable because it reduces testing time, gives instantaneous scoring, increases test security, and can be more easily administered than paper-and-pencil tests. Computer based testing can also be used for pedagogical purposes other than student assessment. For example, it could contribute to students' class performance by providing direct feedback about the adequacy of their studying and learning. In such a situation, computers could be used to administer and score practice tests on demand, thereby giving students immediate

feedback about their knowledge as well as preparation for a pending paper-and-pencil exam (Gretes & Green, 2000).

In 1998, a Computer Based Training project was developed to support the training of pharmacological students. This project demonstrated an excellent use of computers in education. The project developed various types of software for use in pharmacology courses: course organization, simple drill, tutorials, and simulations. These different types of software were used in different ways to achieve very different learning objectives and gains in teaching efficiency. Experience has shown that it is insufficient simply to make this material available to students. It must be fully integrated into a teaching unit if real benefits are to be obtained. In addition, students need to be taught how to learn from computer based materials and how to integrate these learning tools within the rest of their learning strategies. Teachers need to be supported not only with information about the availability of software but, equally importantly, about how it can be integrated into teaching topics (Hughes, 1998).

Another Computer Based Training system was developed to instruct college level students on statistics. Lectures

seem to provide an efficient and effective method for introducing statistical concepts. Even so, it is often difficult for most students to really understand the nature of a statistical problem, nor the intuitive underpinnings that lead to a solution. Typically 85% or more of the students rate statistical courses as either good, or very good. When asked to rate the importance of the computer labs, 70% to 80% of the students feel they were important, with 10% or less assessing computer labs as not important. About 40% of the students said that the computer lab was beneficial in that the computer labs helped their understanding of the statistical topics (Cabilio & Farrell, 2001).

An essential part of learning is assessment. It provides a measure of what is learned. The main goal of assessment should be to enhance the learning experience. The traditional assessment tools generally focus on isolated facts and techniques and ignore a student's understanding of the larger integrated picture, allowing success based on rote memorization rather than true understanding and in some cases even encouraging superficial approaches. Assessment can be used to learn about the gaps in knowledge and erroneous knowledge. Assessment can focus on problem solv-

ing and reasoning skills. Assessment can be done for authentic tasks that are similar to the tasks performed in real-life. Manual assessment has been found to be a weak form of assessing, but under tight controls can be effective. Other weak forms of assessment include multiple-choice questions, true-false examinations and assessment of memorization (Patel, Russell, & Kinshuk, 1998). Research that evaluates if technology raises test scores has been very much sought after during the past few years (Brunner & McMillan, 1994).

Business and industry also use Computer Based Training but do so from a different perspective. Business is looking to develop or improve the knowledge and skills of its workforce. The continuing development of telecommunication technology has made possible another form of CBI often designated as Online Training (OLT). OLT provides the flexibility and efficiency of CBI as well as the individual attention and support of TBI. OLT communicates training information through computer networks such as the Internet or a company's Intranet. OLT provides privacy for trainees who are too embarrassed to ask questions. OLT trainees can ask questions by electronic means without being identified by

others. Questions sent to instructors can be labeled as confidential so the instructors will not reveal the identity of the inquirer to anyone else, such as their future supervisors or managers. OLT may also reduce the possibility of biased evaluation by reducing face-to-face contacts between trainees and instructors. In an OLT course that does not require any face-to-face meetings, a student can conceal his or her identity entirely from the instructor. Using aliases, trainees can control for unfair performance evaluation due to gender, race, and other factors. OLT also makes it easy to outsource training or share educational resources among different organizations and companies. OLT puts less emphasis on oral presentation and more on written or hypermedia presentation. User-friendly computer applications for creating visual aids are available as are applications specifically designed for constructing instructional hypermedia documents. Maintaining the quality of OLT according to company standards is important. OLT can be as effective and rigorous as traditional training, as long as quality and standards are maintained. The advantage of OLT and its success or failure depends on whether it can

achieve the same credibility and quality as traditional training (Huang, 1997).

Several trends in education are contributing to the increasing focus on computers. The first of these trends is a gradual shift toward a more student-centered and constructivist approach in education along with a more individualized approach to learning. Another trend is an increased appreciation for the increasingly experienced and improved student motor skills. Improving attitudes of students towards computers has led to an increased focus on CBI. Finally, the explosive increase in the use of computers in general has increased the need to integrate computers into our educational institutions. The administrative benefits of CBI in training are many. Features such as computerized scoring, evaluation of test items, and test editing can save considerable time for teachers. CBI in training may allow more frequent testing and more variability in test scheduling. These factors might eventually allow educators to provide their students with testing on demand. However, despite the convenience of CBI in training, some educators continue to argue that their use may be disadvantageous to some students because some students may in

fact score lower on tests given in this format (Zandvliet & Farragher, 1997).

Meta-Cognitive Analyses

Meta-cognitive analysis is essentially a second level analysis of one or more research documents. It examines the research and makes observations regarding the research and its merits or detriments. Some meta-cognitive analysis may be further removed in that it discusses other meta-cognitive analysis of research. It may address a collection of documents and may include documents of questionable origin. Yet meta-cognitive analysis, often referred to as meta-analysis, is usually well thought out and worthy of consideration.

A form of computer use that is consistent with the constructivist perspective is simulation of a mathematical model that allows the user to manipulate and experiment with mathematics. Drill-and-practice mathematics software is often in the form of computer games or activities that present the practice in an interesting context (McCoy, 1996).

New technologies allow us to increase access to more information, as well as give us the potential to change the

traditional role of teachers. A review of the available literature shows the benefits to students using computers are: better understanding, extra learning resources, access to information, more choice of learning styles, better communications, better feedback, more individual attention to mistakes and in private, more patient and non-judgmental testing, more drill and practice that is more enjoyable, able to work at own pace, and work at a faster pace. No one medium can solve all educational problems. Many results show that technical subjects are better understood using a technical media (Baillie & Percoco, 2000).

A majority of all college students and faculty have some sort of recurring instructional experience with information technology resources and technology based learning activities. At the same time, many students arrive at college, especially community college, lacking basic skills in mathematics and English. Most colleges and universities offer courses in remedial reading, writing, or mathematics and about one-third of all college freshmen take a remedial course. The convergence of computers and under prepared students in many colleges raises concern within the college community. One question leaps into this concern; what are teachers using computers for and how are

teachers using computers for and how are students learning with computers? For colleges with immediate needs and for faculty with limited time to develop computer programs, purchasing commercial software may be the easiest and quickest way to get students learning on computers. Using commercial software to improve college student's skills has yielded mixed results: some commercial software can be more effective than traditional instruction but in other cases, proprietary software can be less effective than traditional instruction. The software purchase solution necessitates a review of each software purchase and its intended use (Kuehner, 1999).

Another concern is the use of computers in education tends to establish three-way relationships that must be respected when developing the uses for technology. The teacher-student-computer triad imposes itself upon each of the three participants. That relationship and their roles are constantly changing. Teachers may have roles that are subordinate or superior depending upon the needs of the triadic relationship at any given moment. This is also true of the other constituent participants. The computer may be in charge from time-to-time and likewise the student at

other times (Jones & Paolucci, 1999). Unlike the traditional classroom instruction, in which students' roles are mostly passive, CBI requires students to proactively become involved in their learning (Lee, 1999).

However, some researchers feel youngsters who are immersed in the popular culture are accustomed to large doses of passive and visual entertainment. They feel students tend to develop a short attention span and expect immediate gratification. Consequently, students are usually ill equipped to study mathematics, because they lack patience, self-discipline, the ability to concentrate for long periods, with inadequate reading comprehension or writing skills (Koblitz, 1996).

An interesting doctoral dissertation using meta-analysis of 21 related studies found an overall effectiveness of computer-assisted instruction for higher order learning in technical education and training within the military forces of the United States. All of the studies had investigated the effectiveness of computer-assisted instruction as compared to traditional instruction. The meta-analysis concluded that the average student in a traditional military class would have improved test scores if

the student had been provided with computer-assisted instruction (Yaakub, M., 1998).

Some studies employ meta-analysis to an extreme and arrive at some interesting conclusions. One such study conducted by Kulik (1994) meta-analyzed over 500 individualized research studies on CBI as compared to TBI. Kulik's findings were that on average students using CBI scored at the 64th percentile on achievement test whereas TBI students scored at the 50th percentile. Kulik also found the CBI students learned faster and had a more positive attitude about learning. Another large meta-analysis was conducted by Sivin-Kachla (1998) on 219 research studies. Conclusions reached by Sivin-Kachla were essentially the same as Kulik.

Emerging themes will help direct future research. One significant theme is the merging of communications and hypermedia. Students can access Internet-based resources and feed them into hypermedia program shells and make the resources more interactive. For example, students can download a literary work in electronic form, and then add navigation buttons, pop-up field buttons, and scanned-picture buttons. The evolving technology is also allowing

teachers and students to access hypermedia programs from the Internet: programs written in a variety of languages, including Java, which permits students to run programs in real time. An issue within knowledge constructivism is the notion of learner control. Briefly, students with a solid knowledge base in a subject benefit more from having higher learner control, whereas students with a fragmented technology base benefit more from a relatively lower learner control. Therefore, students with better computer skills are more effective when they control the computer learning whereas students with fewer or weaker computer skills perform better with less control of the learning environment (Reed & Spuck, 1996).

Summary

This literature review surveyed a broad spectrum of information regarding the advantages and disadvantages of computers in the classroom. It looked at specific basic research comparable to the study undertaken within this paper. It looked at the opinions and findings of many observers regarding the value of instructional technology.

Conclusions are difficult to draw but suggestions and inferences are plentiful. The bulk of the literature is

supportive of CBI. Most findings are cautious but tend to agree that CBI has a place, especially with rote tasks. TBI comes into play as potentially effective where learner-teacher interaction is sought.

CHAPTER THREE
PROJECT METHODOLOGY

Introduction

This project examines the question explored in Chapter 1: is student academic performance enhanced using Computer Based Instruction (CBI) when compared to a traditional lecture or Teacher Based Instruction (TBI) pedagogy?

To best explore that question this project developed and conducted an experiment comparing those two methods of instruction: CBI versus TBI. A classical and common paradigm of research design is the pretest-posttest control-treatment design. Using this design, two groups of subjects are randomly selected, one group is treated and the outcomes of the two groups are analyzed (Ross, 1999).

This project utilizes that model. Essentially, two groups of subjects were selected at random: a control group and an experimental group. The control group was taught a topic using an established TBI lesson plan whereas the experimental group was taught the same topic but with a new CBI lesson plan. A before and after test was performed on each group and those results were statistically compared and analyzed.

The elements of the project are grouped into five categories: planning, resources, component development, the investigation, and the findings. These interdependent categories tended to be sequential yet they resisted isolation. For example, it was necessary to plan the entire project timeline without an exact awareness of all available resources; making appropriate timeline changes as emerging facts dictated.

A discussion of each category follows.

Planning

This investigation used the classical research model as discussed above. Students within a high school mathematics setting were randomly assigned to one of two groups. One group, the control group, was taught a topic on basic fraction manipulation. This TBI unit was a normally scheduled refresher class provided to all mathematics students. The second group, the experimental group, was taught the same lesson but instead of using the TBI lesson, a new CBI lesson was used instead. The two groups were tested before and after the lessons using the same test instruments. These outcomes were analyzed for variances in test performance using traditional statistical techniques.

Investigation design consists of the overall planning, timeline and procedures for the entire project. This project essentially consisted of six consecutive stages: develop project treatment and instrument, identify group members, conduct pre-test, conduct investigation (CBI/TBI), conduct posttest, and capture and evaluate the outcomes.

Prior to this project, no CBI lesson existed as part of the school curriculum. An in-depth review of the Internet did not disclose any instructional web sites whose lesson structure exactly matched that of the TBI lesson. Development of a web site providing a CBI lesson matching the existing TBI lesson was elected.

Critical Path Methodology (CPM) assumes that any task in a project that takes more time to complete as compared to other tasks is defined as the critical path. CPM further dictates that the overall project timeline is controlled by the critical path timeline. Customarily, when designing a project and assigning development sequence to the project tasks, critical path tasks are scheduled first or as near as first as possible (Meidt, 2001).

The CBI web site development task was expected to take approximately 4 weeks to complete and therefore was the

critical path in this project. Consequently, the CBI web site development task was scheduled first.

Resources

The resource category of this project consisted of three primary components: time, location and subjects. Although in the abstract all components of the investigation could be considered resources, these three are more easily measured and consumed by the project.

A discussion of each resource element follows.

Time

The elapsed time necessary to complete the entire project was about ten weeks. The central part of the project, the investigation, lasted about two weeks and contained three events: pretest, treatment, and posttest. Each event took an entire day to conduct and was separated from the other two events by exactly one week, actually consuming only three of the subjects' classroom days.

The school administration felt it was important that this project had no discernable impact upon any normal and expected curriculum. This expectation was satisfied. Most pedagogical lesson schedules have a few extra days available each year to accommodate unforeseen events. The re-

fresher lesson was usually presented during the course of each semester when need and time permitted by utilizing any available slack days. Sufficient slack time was available this year to conduct this investigation.

Before conducting the web-based treatment, approximately four weeks was needed to produce the web site. Following the treatment and testing, another three weeks was needed to statistically evaluate the results.

Setting

The entire study took place within the high school grounds at two locations. One location was a classroom, under teacher control, and the other location was a computer lab under the control of the School Librarian. This latter location developed a scheduling problem during project execution wherein the experimental group was unable to use the computer lab as scheduled. Alternate facilities were found in other classrooms. This necessitated breaking the experimental group into groups of ten students on average. No consequences of this change were conjectured nor observed.

Potential Subjects

Potential subjects of this study were all the students assigned to the teacher during each class period of the

day. There were four Geometry classes each day consisting of 94 students, and two Advanced Algebra classes each day consisting of 62 students. A period lasted 54 minutes and encompassed one unit of instruction as defined by the schedule contained in the teacher's edition of the Glenco Geometry and Advanced Algebra textbooks.

Student characteristics appeared nominal. The intelligence, cultural, gender, and age distribution of this particular sample population was normal for any random selection of this high school's students. Since these classes were voluntary and not required for graduation, these students had a positive attitude towards the study of mathematics. However, student attitude was not tested. Student cultural base stems from a mixture of Mexican and American customs and values. Gender was about equally divided, and subject ages ranged from 14 through 17 years old, with a mean of 15.5 years. Student academic attitudes in this sample appear typical for a normal group of high school students where most want to achieve well and demonstrate that achievement.

Treatment Selection

Fraction manipulation is a critical element of any cogent mathematical knowledge. Most students lack optimal fraction manipulation skills and therefore a fraction manipulation review is desirable during each semester.

Fraction manipulation was selected as the optimum topic to use in the treatment element of this project. Student familiarity with fractions was sufficient enough to aid the investigator by avoiding the inherent difficulties usually encountered when teaching a new concept.

Project components were a fraction skills pretest and posttest, a traditional lecture based fraction lesson (TBI), and the project treatment - a computer based fraction lesson (CBI). The TBI lesson existed prior to the project and is simply a review of arithmetic fraction manipulation: adding, subtracting, multiplying, dividing, and converting into and out of fractions; without the aid of calculators.

The CBI lesson as conducted did not exist prior to the project. Effective stand-alone software and Internet based web sites that provide hands-on fraction instruction were limited and lacked relevance with this project. The inves-

tigation required the CBI lesson to mirror the TBI lesson in structure, content, perspective, and pedagogical style. In support of these requirements a web site was developed. Details of the web site development are discussed within the Development Section below.

Instrument Options

The pre and posttest is the same test. It is a multiple-choice test consisting of a sufficient number of problems permitting a student to demonstrate their fraction manipulation skills. Variations of the test are available to reduce local contamination, or cheating. The test was administered prior to the TBI and CBI lessons and was administered again after the TBI and CBI lessons. The test is assumed valid by virtue of its approval for use by the Department of Education of the State of California. The test was generated using the Glencoe Publication Mathematics Test Bank Generator program as provided to all secondary mathematics teachers using Glencoe textbooks. The generated test is a multiple-choice test with four or five choices for each problem. The test contains 41 problems focusing on simple problems not requiring the use of a calculator for the majority of students and was administered without the

use of calculators. The test was created with three versions to reduce local contamination, or cheating. Versions in this case were variations wherein the problems remain the same between versions but the multiple choices were randomized. The tests consist solely of simple fraction problems within eight operational categories: (1) addition, (2) subtraction, (3) multiplication, (4) division, (5) changing fractions to decimal numbers, (6) changing decimal numbers to fractions, (7) changing mixed numbers to improper fractions, and (8) changing improper fractions to mixed numbers. Appendix A contains the test and the answer key.

Development

Development in support of this project entails four tasks: a random selection of subjects from the available student pool, the composing of a website for use in the treatment, production of the measuring instrument, and selection of the statistical analysis techniques and supporting software. In addition, the decision to use a two-tailed t -test instead of a one-tailed t -test is discussed below.

Select Subjects

In total 156 students within six class periods were available for assignment. This population permitted 78 students for each of two groups. This is a very comfortable margin since a statistical rule-of-thumb requires each group to be no less than 30. Students were assigned to one of two groups: the TBI control group and a CBI experimental group. Group membership was randomized by class: period five and six were assigned to the TBI control group, periods one and four were assigned to the CBI experimental group, and periods two and three were unassigned.

Develop Website

In the first stage, all of the treatment components are constructed and prepared for use. Since the TBI lesson existed then no effort was required other than to review the lesson for consistency within the project. The CBI lesson needed complete development from scratch.

CBI used the TBI lesson as a presentation template. The CBI lesson currently resides at web site <http://www.Algebra3.com> and is scheduled to reside there indefinitely. Screen shots of the web site structure, Home Page and subordinate pages are displayed in Appendix B.

Produce Instrument

The test generator was discussed in detail above. Generally, the test instrument was a multiple-choice test consisting of 41 questions regarding fractions. It was created through the test generator program provide with the Glenco textbooks. This test generator is a part of the Glenco mathematics products utilized at the high school.

Select Data Analysis Technique

A proprietary Excel spreadsheets statistical add-in, ANALYSE-IT, was utilized in developing the findings. ANOVA one-way tests were not performed in that the statistical software used in this investigation requires control and experimental groups to contain the same number of subjects. In this study, the CBI and TBI groups were of different sizes. ANOVA is an extension of statistical t tests for uses where impact variables are being considered. The simplicity of this study permits basic t test techniques to satisfy the statistical analysis.

One-tailed Versus Two-tailed Testing

Whether to use a one-tailed p-value test or a two-tailed p-value test to test a null hypothesis is controversial. Generally, if only one tail has meaning and the other

tail has no meaning then a one-tailed test is appropriate. However, when only one tail is all that is of value but the other tail may exist and such existence may have probative value, then it is appropriate to do a two-tailed p-value test (Myung, 2000).

For example, if a new drug is only being tested for a decrease in blood pressure then one tail would reflect a decrease in blood pressure, and the other tail would reflect an increase in blood pressure. In this case, a two-tailed p-value test is appropriate. However, if a test of some children's growth rate is under study, it is reasonable to presume any negative growth is meaningless and unlikely, and therefore a one-tailed p-value test is appropriate.

This investigation looks at a change in student test results following a treatment. The results include a diminution in test results as well as an improvement in test results. A review of the data indicates that in fact some student performance significantly decreased. Therefore, in this case it is appropriate to use a two-tailed p-test, even if only one tail is of most interest. No analysis nor conjecture of diminutive performance was performed.

Investigation

The execution of the first investigative tasks took the longest amount of time due to the impact of the CBI web-site development. Conversely, it only took a few days to evaluate the TBI and prepare the pretest and the posttest.

The central tasks were then scheduled: the pre-test took place on a Tuesday, the TBI lesson and the CBI lesson took place the following Tuesday, and the posttest was administered the Tuesday after that. The elapsed time from pre-test through posttest was two weeks and a day. The reasoning for a one-week break between stages was in consideration of other curriculum scheduling needs of the high school.

The statistical evaluation stage had an elapsed timeline of about three weeks.

Pretest

The pre-test was given on the same day to all students in all classes even though two periods of all classes did not participate in the study. That approach minimized group cross contamination. This test established a base of

knowledge of the subjects for future evaluation. The results were encoded and placed onto an Excel spreadsheet.

Treatment

The third stage consists of scheduling the CBI and conducting the TBI. The CBI group received no instruction on fraction manipulation but did receive instructions on how to access the web site for the lesson. They were permitted to visit and revisit the site and collaborate as they chose and when; such as after class or school. The TBI group received only one classroom lesson. See Appendix B and C for examples.

Posttest

This stage consists of the posttest. Here again the test was given on the same day to all students in all classes even though two periods did not participate in the study. The results were encoded and placed upon an Excel spreadsheet for further processing.

Data Collection

The last stage processed and evaluated the test experience. This stage consisted of using standard t test statistical techniques comparing the before-instruction and after-instruction test results.

The null hypothesis conjectured was that the before and after training results between CBI and TBI were the same within a 95% confidence interval.

Another requirement was that all students not participating in all segments of the project be excluded from the statistical base.

Findings

This study had a statistical adjustment wherein 21 subjects were dropped from the analysis due to incomplete participation: such as absence from the pretest, the post-test, or both. The TBI control group began with 63 subjects but 11 were eventually excluded whereas the CBI experimental group began with 49 subjects and 10 were eventually excluded.

A test of the similarity between the control group (TBI) and the experimental group (CBI) before treatment, showed an average performance difference within 7% of each other. Statistically this is considered trivial. This t test p value was 0.6624. We may infer that the two groups were similar.

After treatment, the CBI experimental group showed a small but measurable performance gain with about 82.5% of

the students improving on average by about 6%. Statistically this is considered moderate. The t test p value was 0.0850.

However, after treatment the TBI control group showed a significant performance gain with about 97.5% of the students improving on average by about 5%. The t test p value was 0.0850.

The statistics suggest that of the CBI students, those who improved using CBI, learned more than the TBI students who improved. But we can also infer that more TBI students improved than CBI students.

Table 1. Statistical Findings

Computer Based Instruction: Experimental Group
 N= 39 (cases excluded: 10 due to missing values)

Test Results	n	Mean	SD	SE
Pre-Test	39	24.4	10.0	1.60
Post-Test	39	25.9	9.8	1.57
Difference	39	-1.5	5.3	0.84

Difference between means -1.5
 95% CI -3.2 to 0.2
 t statistic -1.77
 DF 38
 2-tailed p= 0.0850

Teacher Based Instruction: Control Group
 N= 52 (cases excluded: 11 due to missing values)

Test Results	n	Mean	SD	SE
Pre-Test	52	24.3	8.4	1.16
Post-Test	52	25.6	8.9	1.24
Difference	52	-1.3	4.2	0.58

Difference between means -1.3
 95% CI -2.5 to -0.2
 t statistic -2.30
 DF 51
 2-tailed p= 0.0254

Similarity between the control group and the experimental group before treatment
 N= 95 (cases excluded: 17 due to missing values)

Group Results	n	Mean	SD	SE
Computer Based Instruction	42	23.6	10.1	1.56
Teacher Based Instruction	53	24.5	8.4	1.16

Difference between means -0.834
 95% CI -4.6 to 2.9
 t statistic -0.44
 DF 93
 2-tailed p= 0.6623

Summary

This project focused on answering the question considered in chapter 1; is student performance enhanced using Computer Based Instruction (CBI) when compared to a traditional lecture or Teacher Based Instruction (TBI).

The resources and their allocation, the project development and its execution, and the project findings were discussed in this chapter.

The overall project and its conduct were as planned. The findings deviated from many other studies, as discussed in chapter 2. This deviation found TBI to improve performance more comprehensively than CBI.

CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATIONS

Introduction

This project spanned approximately two months. It was conducted as planned and understandable results were obtained. However, the statistical results of this project were different from the majority of the results of similar studies.

Conclusions

Within the boundaries of this project, TBI has been shown to improve the performance of students more extensively than CBI.

There is a five percent average performance improvement within the TBI group and a six percent average performance improvement within CBI group. However, this slight advantage of CBI over TBI is more than offset by a more extensive result wherein TBI encompasses about 97% of the subjects whereas CBI encompasses about 82% of the subjects. Clearly, both forms of instruction improve performance but TBI is more dependable.

These findings suggest that CBI is of more value to a smaller base of students whereas TBI is of value to a

broader base of the student body. This appears suitable in that almost all students have sufficient skills to derive learning from TBI due to an educational experience of that genre whereas a lesser number of students are technically proficient enough to benefit from CBI.

Although not easily determined, bias may have influenced this study. Possibly the TBI students were coached to do better than they normally would have. Conversely, the CBI students may have been coached to do more poorly. Possibly the web site development was biased as to further negatively affect a students learning.

A clear conclusion is that teachers matter. Teachers do have an impact on students learning. Perhaps some amalgam of teacher-computer is the ultimate ideal. Simply put, Students prefer interacting with teachers, but enjoy computers (Crowell, E. 1992).

Recommendations

This study needs purification through reliability assurance. Using statistical bootstrapping did suggest a reliable test but bootstrapping is controversial. Traditional reliability test requires an ability to recreate the same results with the same test at another time.

A larger student sample across many schools of varying and diverse socio-economic strata could balance any subtle biases introduced by the test subjects. Likewise, many different teachers of varying forms of teacher-student familiarity could balance any subtle biases introduced by the teachers.

The statistical analysis of the before and after results should be by someone other than the teacher to maintain impartiality.

With this project, it was initially decided to have the CBI mirror the TBI. That decision was based upon an assumption that CBI could effectively mirror TBI.

This may have flaws in that TBI and CBI are different media and as such may necessitate a different forms of presentation. Therefore the web site should be redesigned to take advantage of what is currently known as how to instruct successfully through the Internet.

As each twist of technology presents itself questions will arise as to its pertinence within the educational industry. This study and many like it answer these questions, and always exposes other questions, such as the value of the teacher-student relationship, and so on.

Summary

This project needs to continue, both in breadth and in depth. It needs to expand and be more critical of its conduct. This initial project found positive value in both CBI and TBI. It also found an interesting variance suggesting teachers are key resources. All variances need explanation but often these explanations become a study unto themselves.

This investigation suggests the following conclusion: students with computer skills benefit best with the use of CBI. However, most students benefit from TBI whether or not they have computer skills.

APPENDIX A
PRETEST AND POSTTEST

**Fraction Test
Version 2
ETEC600 Project (Sawtelle)**

PLEASE SELECT THE BEST ANSWER

1. If $\frac{20}{8}$, $\frac{12}{7}$, $\frac{24}{3}$, and $\frac{20}{6}$ are placed in order from least to greatest, which would be first?
[A] $\frac{12}{7}$ [B] $\frac{24}{3}$ [C] $\frac{20}{6}$ [D] $\frac{20}{8}$

2. If $\frac{24}{5}$, $\frac{25}{2}$, $\frac{23}{7}$, and $\frac{10}{8}$ are placed in order from least to greatest, which would be first?
[A] $\frac{25}{2}$ [B] $\frac{23}{7}$ [C] $\frac{24}{5}$ [D] $\frac{10}{8}$

3. If $\frac{23}{7}$, $\frac{13}{4}$, $\frac{25}{2}$, and $\frac{16}{7}$ are placed in order from least to greatest, which would be first?
[A] $\frac{25}{2}$ [B] $\frac{23}{7}$ [C] $\frac{16}{7}$ [D] $\frac{13}{4}$

4. If $\frac{10}{3}$, $\frac{14}{6}$, $\frac{15}{8}$, and $\frac{19}{3}$ are placed in order from least to greatest, which would be first?
[A] $\frac{10}{3}$ [B] $\frac{14}{6}$ [C] $\frac{19}{3}$ [D] $\frac{15}{8}$

5. Write the numbers in order from least to greatest: $\frac{8}{11}$, $\frac{10}{13}$, 0.748252
[A] 0.748252, $\frac{8}{11}$, $\frac{10}{13}$ [B] $\frac{8}{11}$, 0.748252, $\frac{10}{13}$
[C] $\frac{10}{13}$, 0.748252, $\frac{8}{11}$ [D] 0.748252, $\frac{10}{13}$, $\frac{8}{11}$

**Fraction Test
Version 2
ETEC600 Project (Sawtelle)**

PLEASE SELECT THE BEST ANSWER

6. Write the numbers in order from least to greatest. $\frac{3}{7}, \frac{5}{8}, 0.328571$

[A] $\frac{5}{8}, \frac{3}{7}, 0.328571$

[B] $0.328571, \frac{5}{8}, \frac{3}{7}$

[C] $\frac{3}{7}, \frac{5}{8}, 0.328571$

[D] $0.328571, \frac{3}{7}, \frac{5}{8}$

7. Write the numbers in order from least to greatest. $\frac{2}{3}, \frac{8}{11}, 0.566667$

[A] $0.566667, \frac{8}{11}, \frac{2}{3}$

[B] $\frac{8}{11}, \frac{2}{3}, 0.566667$

[C] $\frac{2}{3}, \frac{8}{11}, 0.566667$

[D] $0.566667, \frac{2}{3}, \frac{8}{11}$

8. Write the numbers in order from least to greatest. $\frac{7}{9}, \frac{9}{13}, 0.735043$

[A] $\frac{9}{13}, 0.735043, \frac{7}{9}$

[B] $\frac{7}{9}, 0.735043, \frac{9}{13}$

[C] $0.735043, \frac{7}{9}, \frac{9}{13}$

[D] $0.735043, \frac{9}{13}, \frac{7}{9}$

9. Find a number between $\frac{11}{20}$ and $\frac{9}{10}$.

[A] $\frac{9}{20}$

[B] $\frac{7}{10}$

[C] $\frac{1}{2}$

[D] $\frac{19}{20}$

Fraction Test
Version 2
ETEC600 Project (Sawtelle)

PLEASE SELECT THE BEST ANSWER

10. Find a number between $\frac{1}{4}$ and $\frac{3}{5}$.

[A] $\frac{1}{5}$

[B] $\frac{13}{20}$

[C] $\frac{3}{20}$

[D] $\frac{9}{20}$

11. Find a number between $\frac{11}{20}$ and $\frac{9}{10}$.

[A] $\frac{19}{20}$

[B] $\frac{9}{20}$

[C] $\frac{4}{5}$

[D] $\frac{1}{2}$

12. Find a number between $\frac{13}{20}$ and $\frac{19}{20}$.

[A] $\frac{11}{20}$

[B] $\frac{3}{5}$

[C] $\frac{3}{4}$

[D] 1

Find the sum.

13. $\frac{4}{9} + \frac{4}{15}$

[A] $\frac{8}{24}$

[B] $\frac{32}{45}$

[C] $\frac{98}{135}$

[D] $\frac{1}{3}$

14. $\frac{3}{20} + \frac{3}{25}$

[A] $\frac{137}{500}$

[B] $\frac{2}{15}$

[C] $\frac{6}{45}$

[D] $\frac{27}{100}$

Fraction Test
Version 2
ETEC600 Project (Sawtelle)

PLEASE SELECT THE BEST ANSWER

Find the sum.

15. $\frac{3}{10} + \frac{1}{8}$

[A] $\frac{2}{5}$

[B] $\frac{17}{40}$

[C] $\frac{2}{9}$

[D] $\frac{4}{18}$

16. $\frac{1}{15} + \frac{3}{10}$

[A] $\frac{4}{25}$

[B] $\frac{11}{30}$

[C] $\frac{53}{150}$

[D] $\frac{2}{9}$

17. Find the difference. $\frac{1}{7} - (-4)$

[A] $\frac{5}{7}$

[B] $\frac{29}{7}$

[C] $-\frac{27}{7}$

[D] -4

18. Find the difference. $\frac{1}{4} - (-2)$

[A] $\frac{3}{4}$

[B] $\frac{9}{4}$

[C] -2

[D] $-\frac{7}{4}$

19. Find the difference. $-\frac{1}{7} - (-1)$

[A] -1

[B] $\frac{6}{7}$

[C] $-\frac{8}{7}$

[D] 0

**Fraction Test
Version 2
ETEC600 Project (Sawtelle)**

PLEASE SELECT THE BEST ANSWER

20. Find the difference. $\frac{1}{3} - (-1)$

[A] $-\frac{2}{3}$

[B] -1

[C] $\frac{4}{3}$

[D] $\frac{2}{3}$

Find:

21. $\frac{5}{6} - 5\left(\frac{4}{7} + 3\right)$

[A] $-5\frac{1}{42}$

[B] $-17\frac{1}{42}$

[C] $17\frac{1}{42}$

[D] $5\frac{1}{42}$

22. $\frac{3}{4} - 5\left(\frac{1}{2} + 4\right)$

[A] $-5\frac{3}{4}$

[B] $21\frac{3}{4}$

[C] $-21\frac{3}{4}$

[D] $5\frac{3}{4}$

23. $\frac{1}{3} - 4\left(\frac{4}{5} + 7\right)$

[A] $23\frac{7}{15}$

[B] $30\frac{13}{15}$

[C] $-30\frac{13}{15}$

[D] $-23\frac{7}{15}$

24. $\frac{4}{7} - 4\left(\frac{2}{3} + 3\right)$

[A] $-6\frac{17}{21}$

[B] $-14\frac{2}{21}$

[C] $6\frac{17}{21}$

[D] $14\frac{2}{21}$

**Fraction Test
Version 2
ETEC600 Project (Sawtelle)**

PLEASE SELECT THE BEST ANSWER

Find the product.

25. $\frac{9}{4} \cdot \left(-\frac{9}{5}\right)$

- [A] 0 [B] $-\frac{81}{20}$ [C] $\frac{81}{20}$ [D] $-\frac{5}{4}$

26. $\frac{7}{5} \cdot \left(-\frac{5}{2}\right)$

- [A] $-\frac{7}{2}$ [B] $\frac{7}{2}$ [C] $-\frac{14}{25}$ [D] $\frac{1}{5}$

27. $\frac{8}{7} \cdot \left(-\frac{9}{7}\right)$

- [A] $-\frac{72}{49}$ [B] $-\frac{1}{49}$ [C] $\frac{72}{49}$ [D] $-\frac{8}{9}$

28. $\frac{7}{9} \cdot \left(-\frac{6}{5}\right)$

- [A] $-\frac{35}{54}$ [B] $\frac{1}{45}$ [C] $\frac{14}{15}$ [D] $-\frac{14}{15}$

Find the quotient.

29. $\frac{1}{4} \div \left(-\frac{7}{8}\right)$

- [A] $-\frac{7}{32}$ [B] $-\frac{2}{7}$ [C] $\frac{2}{7}$ [D] $\frac{7}{32}$

**Fraction Test
Version 2
ETEC600 Project (Sawtelle)**

PLEASE SELECT THE BEST ANSWER

Find the quotient.

30. $\frac{1}{6} \div \left(-\frac{5}{12}\right)$

- [A] $\frac{5}{72}$ [B] $-\frac{5}{72}$ [C] $-\frac{2}{5}$ [D] $\frac{2}{5}$

31. $\frac{3}{4} \div \left(-\frac{2}{8}\right)$

- [A] -3 [B] $\frac{3}{16}$ [C] $-\frac{3}{16}$ [D] 3

32. $\frac{2}{7} \div \left(-\frac{1}{21}\right)$

- [A] 6 [B] $\frac{2}{147}$ [C] $-\frac{2}{147}$ [D] -6

33. If $\frac{16}{7}$, $\frac{19}{7}$, $\frac{14}{4}$, and $\frac{24}{3}$ are placed in order from least to greatest, which would be first?

- [A] $\frac{14}{4}$ [B] $\frac{24}{3}$ [C] $\frac{19}{7}$ [D] $\frac{16}{7}$

34. Write the numbers in order from least to greatest. $\frac{7}{8}$, $\frac{5}{6}$, 0.854167

- [A] 0.854167, $\frac{7}{8}$, $\frac{5}{6}$ [B] $\frac{5}{6}$, 0.854167, $\frac{7}{8}$

- [C] $\frac{7}{8}$, -0.854167, $\frac{5}{6}$ [D] 0.854167, $\frac{5}{6}$, $\frac{7}{8}$

Fraction Test
Version 2
ETEC600 Project (Sawtelle)

PLEASE SELECT THE BEST ANSWER

35. Find a number between $\frac{9}{20}$ and $\frac{9}{10}$.

[A] $\frac{7}{20}$

[B] $\frac{13}{20}$

[C] $\frac{2}{5}$

[D] $\frac{19}{20}$

36. Find the sum: $\frac{1}{10} + \frac{3}{20}$

[A] $\frac{4}{30}$

[B] $\frac{1}{4}$

[C] $\frac{13}{50}$

[D] $\frac{2}{15}$

37. Find the difference: $\frac{1}{8} - (-1)$

[A] $\frac{1}{4}$

[B] $\frac{9}{8}$

[C] $-\frac{7}{8}$

[D] -1

38. Find: $\frac{1}{5} - 2\left(\frac{2}{5} + 2\right)$

[A] $-2\frac{3}{5}$

[B] $-4\frac{3}{5}$

[C] $4\frac{3}{5}$

[D] $2\frac{3}{5}$

39. Find the product: $\frac{2}{3} \cdot \left(-\frac{4}{3}\right)$

[A] $-\frac{2}{9}$

[B] $-\frac{8}{9}$

[C] $\frac{8}{9}$

[D] $-\frac{1}{2}$

**Fraction Test
Version 2
ETEC600 Project (Sawtelle)**

PLEASE SELECT THE BEST ANSWER

Find the quotient.

40. $\frac{1}{5} \div \left(-\frac{5}{10}\right)$

[A] $-\frac{1}{10}$

[B] $-\frac{2}{5}$

[C] $\frac{2}{5}$

[D] $\frac{1}{10}$

41. $\frac{2}{7} \div \left(-\frac{7}{21}\right)$

[A] $-\frac{2}{21}$

[B] $-\frac{6}{7}$

[C] $\frac{6}{7}$

[D] $\frac{2}{21}$

**Fraction Test
Version 2
ETEC600 Project (Sawtelle)**

PLEASE SELECT THE BEST ANSWER

- [1] A
- [2] D
- [3] C
- [4] D
- [5] B
- [6] D
- [7] D
- [8] A
- [9] B
- [10] D
- [11] C
- [12] C
- [13] B
- [14] D
- [15] B
- [16] B
- [17] B
- [18] B
- [19] B

**Fraction Test
Version 2
ETEC600 Project (Sawtelle)**

PLEASE SELECT THE BEST ANSWER

[20] C

[21] B

[22] C

[23] C

[24] B

[25] B

[26] A

[27] A

[28] D

[29] B

[30] C

[31] A

[32] D

[33] D

[34] B

[35] B

[36] B

[37] B

[38] B

**Fraction Test
Version 2
ETEC600 Project (Sawtelle)**

PLEASE SELECT THE BEST ANSWER

[39] B

[40] B

[41] B

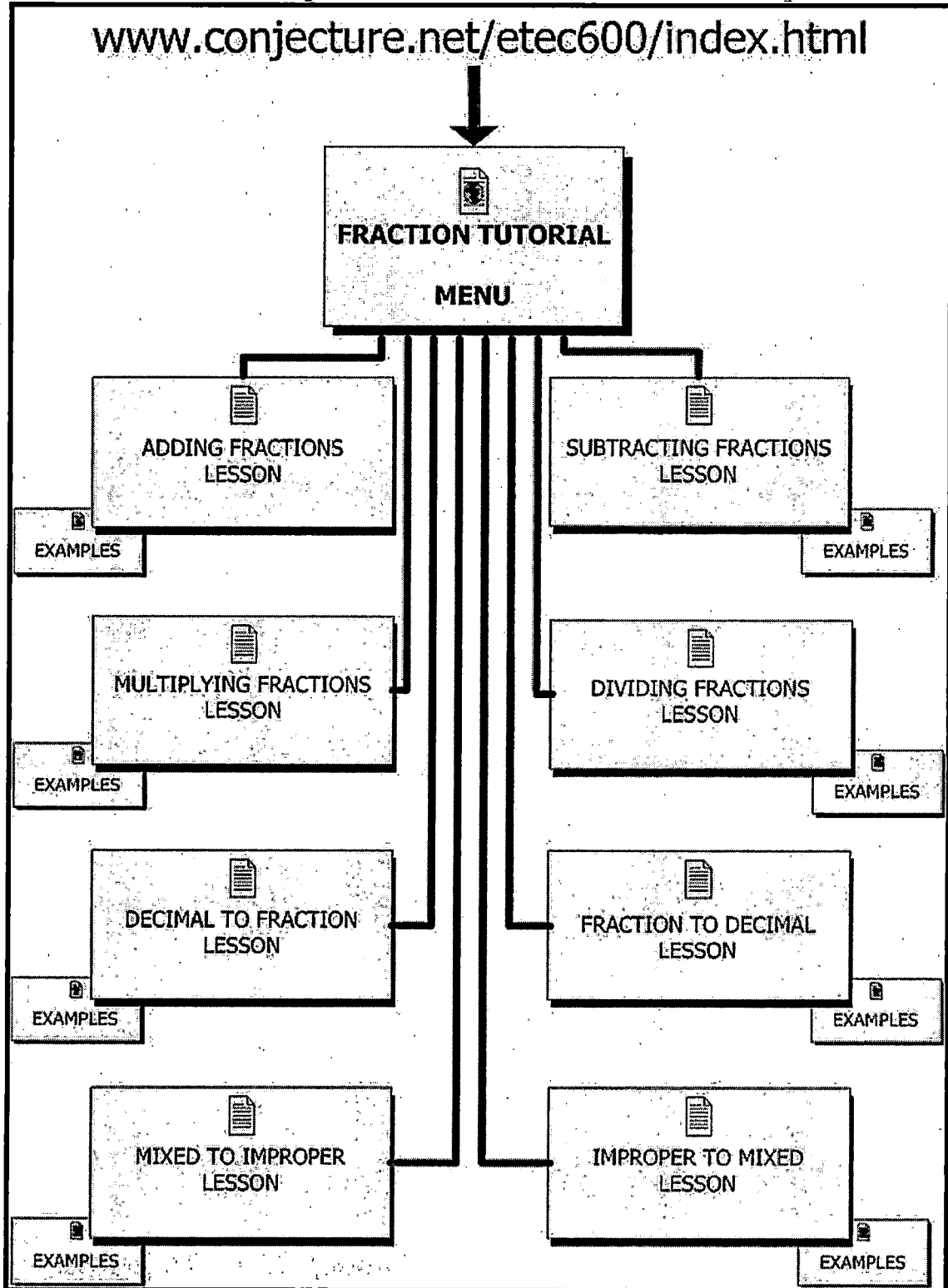
APPENDIX B
COMPUTER BASED INSTRUCTION WEB SITE

COMPUTER BASED INSTRUCTION WEB SITE

Figures and Snapshots

- B-1. Web Site Navigational Structure with Gateway.
- B-2. Fraction Tutorial Menu and Home Page.
- B-3. Adding Fractions Lesson Page.
- B-4. Subtracting Fractions Lesson Page.
- B-5. Multiplying Fractions Lesson Page.
- B-6. Dividing Fractions Lesson Page.
- B-7. Decimal to Fraction Lesson Page.
- B-8. Fraction to Decimal Lesson Page.
- B-9. Mixed Number to Improper Fraction Lesson.
- B-10. Improper Fraction to Mixed Number Lesson Page.
- B-11. Examples: Converting Fractions to Decimals Page.
- B-12. Examples: Adding Fractions Page.
- B-13. Examples: Mixed Numbers to Improper Fractions Page.
- B-14. Examples: Decimal Numbers to Fraction Page.
- B-15. Examples: Dividing Fractions Page.
- B-16. Examples: Improper Fraction to Mixed Number Page.
- B-17. Examples: Multiplying Fractions Page.
- B-18. Examples: Subtracting Fractions Page.
- B-19. Examples: Reducing Fractions Page.

B-1. Web Site Navigational Structure with Gateway



Fractions: Key to Success in Algebra & Geometry

Select a Lesson and Click the boxed graphic

$$\boxed{\frac{b}{c} \Rightarrow \frac{d}{c}}$$

**Mixed Numbers to
Fractions**

$$\boxed{\frac{d}{c} \Rightarrow a\frac{b}{c}}$$

**Fractions to Mixed
Numbers**

$$\boxed{\frac{a}{b} \Rightarrow cd\dots}$$

**Fractions to Decimal
Numbers**

$$\boxed{cd\dots \Rightarrow \frac{a}{b}}$$

**Decimal Numbers to
Fractions**

$$\boxed{\frac{a}{b} + \frac{c}{d}}$$

Adding Fractions

$$\boxed{\frac{a}{b} - \frac{c}{d}}$$

Subtracting Fractions

$$\boxed{\frac{a}{b} \times \frac{c}{d}}$$

Multiplying Fractions

$$\boxed{\frac{a}{b} \div \frac{c}{d}}$$

Dividing Fractions

Fractions: Adding Fractions

$$\frac{a}{b} + \frac{c}{d}$$

PROCESS

$$\frac{a}{b} + \frac{c}{d} \Rightarrow \frac{(a \times d) + (b \times c)}{b \times d} \Rightarrow \frac{e}{f}$$

WHAT?

And Be Sure To Reduce

HOW?

GO BACK

GO HOME

Fractions: Subtracting Fractions

$$\frac{a}{b} - \frac{c}{d}$$

PROCESS

$$\frac{a}{b} - \frac{c}{d} \Rightarrow \frac{(a \times d) - (b \times c)}{b \times d}$$

WHAT?

And Be Sure To Reduce

HOW?

GO BACK

GO HOME

Fractions: Multiplying Fractions

$$\frac{a}{b} \times \frac{c}{d}$$

PROCESS

$$\frac{a}{b} \times \frac{c}{d} \Rightarrow \frac{a \times c}{b \times d}$$

WHAT?

And Be Sure To Reduce

HOW?

GO BACK

GO HOME

Fractions: Dividing Fractions

$$\frac{a}{b} \div \frac{c}{d}$$

PROCESS

$$\frac{a}{b} \div \frac{c}{d}$$

↓

$$\div \frac{c}{d} \xrightarrow[\text{reciprocate fraction}]{\text{invert operation}} \times \frac{d}{c}$$

↓

$$\frac{a}{b} \times \frac{d}{c}$$

WHAT?

And Be Sure To Reduce

HOW?

GO BACK

GO HOME

Fractions: Decimals to Fractions

$$c.d \dots \Rightarrow \frac{a}{b}$$

PROCESS

$$c.d \dots \Rightarrow \frac{a}{b}$$

index is a count of a set

no decimal or $d = 0 \quad c \Rightarrow \frac{c}{1}$

terminated decimal $c.d \Rightarrow c + \frac{d}{\underbrace{10 \dots}_{d \text{ index}}}$

repeating decimal $c.\bar{d} \Rightarrow c + \frac{\bar{d}}{\underbrace{9 \dots}_{\bar{d} \text{ index}}}$

mixed decimal $c.n\bar{d} \Rightarrow c + \frac{n}{\underbrace{10 \dots}_{n \text{ index}}} + \frac{\bar{d}}{\underbrace{9 \dots}_{\bar{d} \text{ index}} \underbrace{0 \dots}_{n \text{ index}}}$

WHAT?

And Be Sure To Reduce

HOW?

Fractions: Fractions to Decimals

$$\frac{a}{b} \Rightarrow c.d\dots$$

PROCESS

$$\frac{a}{b} \Rightarrow \frac{a \div b}{b \overline{)a}} \Rightarrow \begin{cases} c \text{ (no remainder)} \\ c.d \text{ (truncated remainder)} \\ c.\overline{d} \text{ (repeating remainder)} \\ c.n\overline{d} \text{ (mixed remainder)} \end{cases}$$

WHAT?

GO BACK

GO HOME

B-9. Mixed Number to Improper Fraction Lesson.

Fractions: Converting Mixed Numbers to Improper Fractions

$$a\frac{b}{c} \Rightarrow \frac{d}{c}$$

PROCESS

$$a\frac{b}{c} \Rightarrow \frac{(a \times c) + b}{c} \Rightarrow \frac{d}{c}$$

WHAT?

GO BACK

GO HOME

Fractions: Converting Fractions to Mixed Numbers

$$\frac{d}{c} \Rightarrow a\frac{b}{c}$$

PROCESS

$$\frac{d}{c} \Rightarrow c \div d = a + \frac{\text{remainder}}{c} \Rightarrow a\frac{b}{c}$$

WHAT?

GO BACK

GO HOME

$$\frac{a}{b} \Rightarrow \frac{a \div b}{b \overline{)a}} \Rightarrow \begin{cases} c \text{ (no remainder)} \\ c.d \text{ (truncated remainder)} \\ c.\bar{d} \text{ (repeating remainder)} \\ c.n\bar{d} \text{ (mixed remainder)} \end{cases}$$

Example 1 (no remainder)

$$\frac{75}{15} \Rightarrow \frac{75 \div 15}{15 \overline{)75}} = 5$$

Example 2 (truncated remainder)

$$\frac{7}{4} \Rightarrow \frac{7 \div 4}{4 \overline{)7.00}} = 1.75 \quad \text{also} \quad \frac{3}{5} \Rightarrow \frac{3 \div 5}{5 \overline{)3.0}} = 0.6$$

Example 3 (repeating remainder)

$$\frac{4}{3} \Rightarrow \frac{4 \div 3}{3 \overline{)4.000\dots}} = 1.\underbrace{666\dots}_{\text{repeating}} \Rightarrow 1.\bar{6}$$

and

$$\frac{2}{7} \Rightarrow \frac{2 \div 7}{7 \overline{)2.000\dots}} = 0.\underbrace{285714285714\dots}_{\text{repeating decimal}} \Rightarrow 0.\overline{285714}_{\text{repeater}}$$

Example 4 (mixed remainder)

$$\frac{47}{30} \Rightarrow \frac{47 \div 30}{30 \overline{)47.00\dots}} = 1.5\underbrace{666\dots}_{\text{repeating}} \Rightarrow 1.5\bar{6}$$

and

$$\frac{62}{495} \Rightarrow \frac{62 \div 495}{495 \overline{)62.000\dots}} = 0.12525\underbrace{25\dots}_{\text{repeater}} \Rightarrow 0.125\bar{25}$$

B-12. Examples: Adding Fractions Page.

$$\frac{a}{b} + \frac{c}{d} \Rightarrow \frac{(a \times d) + (b \times c)}{b \times d} \Rightarrow \frac{e}{f}$$

Example 1

$$\frac{2}{3} + \frac{1}{4} \Rightarrow \frac{(2 \times 4) + (3 \times 1)}{3 \times 4} \Rightarrow \frac{8 + 3}{12} \Rightarrow \frac{11}{12}$$

Example 2

$$\frac{3}{8} + \frac{5}{6} \Rightarrow \frac{(3 \times 6) + (8 \times 5)}{8 \times 6} \Rightarrow \frac{18 + 40}{48} \Rightarrow \frac{58}{48}$$

B-13. Examples: Mixed Numbers to Improper Fractions Page.

Examples of $a\frac{b}{c} \Rightarrow \frac{(a \times c) + b}{c} \Rightarrow \frac{d}{c}$

Example 1 $2\frac{2}{3} \Rightarrow \frac{(2 \times 3) + 2}{3} \Rightarrow \frac{6 + 2}{3} \Rightarrow \frac{8}{3}$

Example 2 $-1\frac{4}{5} \Rightarrow -\frac{(1 \times 5) + 4}{5} \Rightarrow -\frac{5 + 4}{5} \Rightarrow -\frac{9}{5}$

B-14. Examples: Decimal Numbers to Fraction Page.

$$c.d \dots \Rightarrow \frac{a}{b}$$

"i" is index. It is a count of a set

$$\text{no decimal or } d = 0 \quad c \Rightarrow \frac{c}{1}$$

Example 1

$$7.0 \Rightarrow \frac{7}{1} \quad \text{or} \quad -5 \Rightarrow -\frac{5}{1}$$

$$\text{terminated decimal} \quad c.d \Rightarrow c + \frac{d}{\underbrace{10 \dots}_{d \text{ index}}}$$

Example 2

$$7.4 \Rightarrow 7.\underbrace{4}_{i=1} \Rightarrow 7 + \frac{4}{\underbrace{10}_{i=1}} \quad \text{or} \quad 0.\underbrace{075}_{i=3} \Rightarrow 0 + \frac{075}{\underbrace{1000}_{i=3}} \Rightarrow \frac{75}{1000}$$

$$\text{repeating decimal} \quad c.\bar{d} \Rightarrow c + \frac{d}{\underbrace{9 \dots}_{\bar{d} \text{ index}}}$$

Example 3

$$2.\bar{3} \Rightarrow 2.\underbrace{\bar{3}}_{i=1} \Rightarrow 2 + \frac{3}{\underbrace{9}_{i=1}} \quad \text{or} \quad 0.\underbrace{\bar{125}}_{i=3} \Rightarrow \frac{125}{\underbrace{999}_{i=3}} \Rightarrow \frac{125}{999}$$

$$\text{mixed decimal} \quad c.n\bar{d} \Rightarrow c + \frac{n}{\underbrace{10 \dots}_{n \text{ index}}} + \frac{d}{\underbrace{9 \dots 0 \dots}_{\bar{d} \text{ index } n \text{ index}}}$$

Example 4

$$4.6\bar{12} \Rightarrow 4.\underbrace{6}_{i=1} \underbrace{\bar{12}}_{i=2} \Rightarrow 4 + \frac{6}{\underbrace{10}_{i=1}} + \frac{12}{\underbrace{990}_{i=2 \ i=1}} \Rightarrow 4 + \frac{6}{10} + \frac{12}{990}$$

or

$$0.00\bar{6} \Rightarrow 0.\underbrace{00}_{i=2} \underbrace{\bar{6}}_{i=1} \Rightarrow 0 + \frac{00}{\underbrace{100}_{i=2}} + \frac{6}{\underbrace{900}_{i=1 \ i=2}} \Rightarrow \frac{6}{900}$$

B-15. Examples: Dividing Fractions Page.

$$\frac{a}{b} \div \frac{c}{d}$$
$$\Downarrow$$
$$\frac{c}{d} \xrightarrow[\text{reciprocate fraction}]{\text{invert operation}} \times \frac{d}{c}$$
$$\Downarrow$$
$$\frac{a}{b} \times \frac{d}{c}$$

Example 1

$$\frac{1}{2} \div \frac{3}{4}$$
$$\Downarrow$$
$$\frac{3}{4} \xrightarrow[\text{reciprocate fraction}]{\text{invert operation}} \times \frac{4}{3}$$
$$\Downarrow$$
$$\frac{1}{2} \times \frac{4}{3}$$

Example 2

$$\frac{-7}{8} \div \frac{6}{5}$$
$$\Downarrow$$
$$\frac{6}{5} \xrightarrow[\text{reciprocate fraction}]{\text{invert operation}} \times \frac{5}{6}$$
$$\Downarrow$$
$$\frac{-7}{8} \times \frac{5}{6}$$

B-16. Examples: Improper Fraction to Mixed Number Page.

$$\frac{d}{c} \Rightarrow c \div d = a + \frac{\text{remainder}}{c} \Rightarrow a \frac{b}{c}$$

EXAMPLES

r is the remainder of Division

Example 1

$$\frac{12}{7} \Rightarrow \frac{12 \div 7 = 1 + \frac{5}{7}}{\begin{array}{l} 7 \overline{)12} \\ \underline{7} \\ 5 \end{array}} \Rightarrow 1 \frac{5}{7}$$

Example 2

$$-\frac{7}{3} \Rightarrow -\left(\frac{7 \div 3 = 2 + \frac{1}{3}}{\begin{array}{l} 3 \overline{)7} \\ \underline{6} \\ 1 \end{array}}\right) \Rightarrow -2 \frac{1}{3}$$

B-17. Examples: Multiplying Fractions Page.

$$\frac{a}{b} \times \frac{c}{d} \Rightarrow \frac{a \times c}{b \times d} \Rightarrow \frac{e}{f}$$

Example 1

$$\frac{2}{3} \times \frac{5}{6} \Rightarrow \frac{2 \times 5}{3 \times 6} \Rightarrow \frac{10}{18}$$

Example 2

$$-\frac{2}{3} \times \frac{1}{4} \Rightarrow \frac{-2 \times 1}{3 \times 4} \Rightarrow \frac{-2}{12} \Rightarrow -\frac{2}{12}$$

B-18. Examples: Subtracting Fractions Page.

$$\frac{a}{b} - \frac{c}{d} \Rightarrow \frac{(a \times d) - (b \times c)}{b \times d} \Rightarrow \frac{e}{f}$$

Example 1:

$$\frac{2}{3} - \frac{1}{4} \Rightarrow \frac{(2 \times 4) - (3 \times 1)}{3 \times 4} \Rightarrow \frac{8 - 3}{12} \Rightarrow \frac{5}{12}$$

Example 2:

$$\frac{3}{8} - \frac{5}{6} \Rightarrow \frac{(3 \times 6) - (8 \times 5)}{8 \times 6} \Rightarrow \frac{18 - 40}{48} \Rightarrow \frac{-22}{48}$$

B-19. Examples: Reducing Fractions Page.

*To Reduce a fraction,
Divide the Numerator and Denominator
by the greatest value which leaves no remainder.*

$$\frac{c}{d} \Rightarrow \frac{c \div g}{d \div g} \Rightarrow \frac{e}{f}$$

for example, $\frac{4}{6} \Rightarrow \frac{4 \div 2}{6 \div 2} \Rightarrow \frac{2}{3}$

2 is the greatest divisor leaving no remainder.

and $\frac{36}{24} \Rightarrow \frac{36 \div 12}{24 \div 12} \Rightarrow \frac{3}{2}$

12 is the greatest divisor leaving no remainder.

APPENDIX C

TEACHER BASED INSTRUCTION LESSON PLAN

Lesson Plan

TEACHER: John Sawtelle	GRADE LEVEL: 9 - 12
SUBJECT: Algebra 2 / Geometry	UNIT: Fraction Operations Review
TIME: 54 minutes (1 period)	MATERIALS: Paper and Pencil

OVERVIEW: This lesson will review all operations performed on fractions. The purpose is to ensure students are cogent with fractions since fraction manipulation skills are crucial to success in Algebra 2 or Geometry. This lesson conforms to the California Mathematics Standards as adopted by the California Department of Education.

PROCESS:

1. Teacher will discuss the need for a review of fractions; even though students have studied fractions extensively in lower grades they may have become rusty.
2. Topics are demonstrated by teacher in general and with specific examples:
 - Adding Fractions
 - Subtracting Fractions
 - Multiplying Fractions
 - Dividing Fractions
 - Simplifying Fractions
 - Converting Decimals to Fractions (includes repeating decimals)
 - Converting Fractions to Decimals (includes repeating decimals)
 - Improper to Mixed Fractions
 - Mixed to Improper Fractions
3. Students are assigned worksheets as homework to be returned at the next scheduled class.

ASSESSMENT: A multiple choice test is scheduled for the next class.

NOTE: This lesson plan is also being used by John Sawtelle in an academic investigation in support of his master's thesis at CSUSB. For that purpose only the same assessment test is scheduled before the lesson as well as after the lesson.

Feb/2002

APPENDIX D
STATISTICAL SOURCE DATA

Subject	Gender	Level	Group	Pre-test	Post-test
101	F	9	CBI	37	38
102	F	9	CBI	15	20
103	F	9	CBI	36	34
104	M	9	CBI	12	21
105	F	9	CBI		30
106	M	9	CBI	6	14
107	F	9	CBI	37	38
108	M	9	CBI	37	35
109	F	11	CBI	25	22
110	M	9	CBI	39	39
111	F	9	CBI	24	22
112	F	9	CBI	39	39
113	M	9	CBI	35	36
114	M	9	CBI	7	10
115	F	9	CBI	34	35
116	F	9	CBI	26	35
117	M	9	CBI	29	26
118	M	9	CBI	28	28
119	F	9	CBI		
121	M	9	CBI	34	33
401	M	10	CBI		
402	F	10	CBI	26	33
403	M	10	CBI	15	16
404	M	11	CBI	15	20
405	M	11	CBI		32
406	F	10	CBI	13	
407	F	11	CBI	25	23
408	F	10	CBI	23	18
409	F	10	CBI	32	35
410	M	10	CBI		
411	F	10	CBI	31	38
412	F	10	CBI	36	34
413	M	10	CBI	21	24
414	F	10	CBI	19	
415	M	10	CBI	16	8
416	F	11	CBI	23	6
417	F	10	CBI	5	8
418	F	10	CBI	23	23
419	F	10	CBI		10
420	F	10	CBI	30	35
421	M	11	CBI	8	
422	M	10	CBI	22	23
423	M	10	CBI	33	34
424	M	11	CBI	15	28

425	F	10	CBI	15	17
426	M	9	CBI	7	14
427	M	10	CBI	23	30
428	F	11	CBI	16	18
429	F	10	CBI		
501	F	11	TBI		6
502	F	11	TBI	23	29
503	M	10	TBI	36	37
504	F	10	TBI	19	27
505	M	10	TBI	36	33
506	F	10	TBI	38	38
507	F	12	TBI		
508		12	TBI		
509	F	10	TBI	24	16
510	M	10	TBI	31	31
511	F	10	TBI	33	31
512	F	10	TBI	22	18
513	F	10	TBI	34	36
514	M	12	TBI	14	26
515	M	11	TBI	27	30
516	M	12	TBI	12	13
517	F	11	TBI	29	32
518	M	10	TBI	27	27
519	M	9	TBI	35	33
520	M	11	TBI	32	32
521	F	11	TBI		18
522	F	12	TBI	24	27
523	F	10	TBI	25	27
524	M	10	TBI	25	37
525	F	10	TBI	33	37
526	F	11	TBI		17
527	M	10	TBI	24	30
528	M	11	TBI	35	37
529	F	10	TBI	34	37
530	F	12	TBI	22	28
531	M	12	TBI	24	29
532	M	11	TBI		24
533	F	11	TBI	34	32
534	F	10	TBI	37	37
535	M	12	TBI	18	19
601	M	11	TBI	9	13
602	F	10	TBI	33	34
603	F	11	TBI	34	
604	F	10	TBI	21	26
605	M	10	TBI	12	19
606	M	11	TBI	14	9

607	M	11	TBI	11	13
608	F	10	TBI	19	12
609	M	11	TBI	26	29
610	M	10	TBI		22
611	F	11	TBI	26	25
612	F	11	TBI		
613	F	10	TBI	22	25
614	M	9	TBI	34	35
615	M	11	TBI	17	9
616	M	10	TBI	35	34
617	F	10	TBI	14	18
619	M	10	TBI	12	12
620	F	10	TBI	13	12
621	F	11	TBI	9	6
622	M	11	TBI	23	21
623	M	11	TBI	26	23
624	F	10	TBI	27	30
625	F	10	TBI	17	23
626	M	10	TBI	17	17
627	F	10	TBI		19
628	M	11	TBI	11	
629	M	11	TBI	18	21

APPENDIX E
STATISTICAL DETAILS

Computer Group

paired sample t-test

Test Results	n	Mean	SD	SE
Pre-Test	39	24.4	10.0	1.60
Post-Test	39	25.9	9.8	1.57
Difference	39	-1.5	5.3	0.84

Difference between means | -1.5
95% CI | -3.2 to 0.2

t statistic | -1.77
DF | 38
2-tailed p | 0.0850

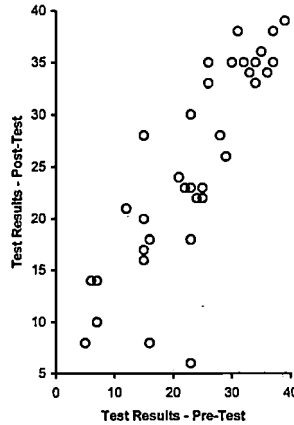
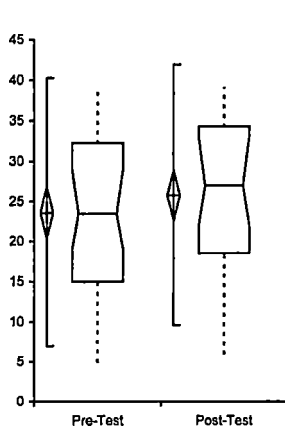
Pearson correlation

n | 39 (cases excluded: 10 due to missing values)
r statistic | 0.86
95% CI | 0.75 to 0.92.

2-tailed p | <0.0001 (t approximation)

Test Results	n	Mean	SD	SE	95% CI of Mean
Pre-Test	42	23.6	10.12	1.56	20.5 to 26.8
Post-Test	42	25.8	9.82	1.52	22.7 to 28.8

Test Results	n	Median	IQR	95% CI of Median
Pre-Test	42	23.5	17.3	19.0 to 29.0
Post-Test	42	27.0	15.8	22.0 to 33.0



Lecture Group

t-test (2-way)				
n 52 (cases excluded: 11 due to missing values)				
Test Results	n	Mean	SD	SE
Pre-Test	52	24.3	8.4	1.16
Post-Test	52	25.6	8.9	1.24
Difference	52	-1.3	4.2	0.58

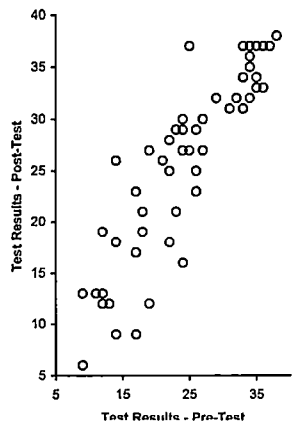
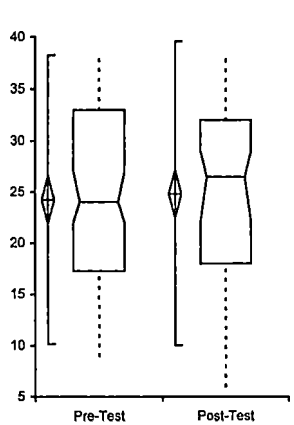
Difference between means -1.3
95% CI -2.5 to -0.2

t statistic -2.30
DF 51
2-tailed p 0.0254

Pearson correlation					
n 52 (cases excluded: 11 due to missing values)					
Test Results	n	Mean	SD	SE	95% CI of Mean
Pre-Test	54	24.2	8.54	1.16	21.9 to 26.5
Post-Test	58	24.8	8.98	1.18	22.4 to 27.2

r statistic 0.88
95% CI 0.80 to 0.93
2-tailed p <0.0001 (t approximation)

Test Results	n	Median	IQR	95% CI of Median
Pre-Test	54	24.0	15.8	22.0 to 27.0
Post-Test	58	26.5	14.0	22.0 to 29.0



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