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Using the Web-based Cognitive Training for Children as an educational intervention: A replication study

by

Jennifer Michelle Riedemann

A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Education

Program of Study Committee:
Gary D. Phye, Major Professor
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Iowa State University

Ames, Iowa

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Graduate College

Iowa State University

This is to certify that the master's thesis of

Jennifer Michelle Riedemann

has met the thesis requirements of Iowa State University

Signatures have been redacted for privacy

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ABSTRACT

The Web-based Cognitive Training for Children was designed to help improve 4th grade students' problem-solving abilities in fractions by teaching inductive reasoning skills, especially for those who may have difficulty in acquiring skills for fractions through regular classroom instruction. The purposes of this study were to further evaluate the effectiveness of the WCTC by addressing concerns raised in an initial pilot study and to investigate the comparative effects of the WCTC program with students who are identified as low, medium, and high performers.

Participants were six 4th grade classes. Using a block randomization design, three classes with 73 students were assigned to the training group to receive training in inductive reasoning skills using the WCTC program, and three classes with 70 students were assigned to the control group to practice fraction problems on educational web sites. A pretest-posttest design was employed in this study.

Results indicate that the WCTC program is effective in improving students' problem-solving abilities with fractions, with the middle performance group demonstrating the greatest gains in performance. The influence of other factors such as reading achievement were also examined. The information gained in this study provides empirical evidence concerning the instructional effectiveness of the WCTC program as an educational intervention.

CHAPTER 1: INTRODUCTION AND LITERATURE REVIEW

1.1 The "Cognitive Training for Children" Program

The *Cognitive Training for Children* is a program designed to promote inductive thinking and problem solving abilities in young children. It was originally introduced in Germany by Josef Klauer (Klauer, 1989), and has since been translated for use in both the United States (Klauer & Phye, 1994) and the Netherlands (Klauer, Resing, & Slenders, 1996).

The program is devoted to fostering the development of procedural learning strategies that are part of a logical reasoning structure. The basic thinking processes of inductive reasoning are taught using examples within a problem-solving context, with the goal that the child will then transfer the inductive reasoning procedures to practical situations.

The theoretical rationale of the program is a combination of aptitude theory and a cognitive information processing approach to reasoning and problem solving. Current aptitude theory views aptitudes as cumulative learning potentials that develop through practice. Generalization, discrimination, and monitoring for similarities/differences are seen as aptitudes that are a necessary preparation for the development of inductive reasoning and problem solving abilities (Klauer & Phye, 1994).

According to Klauer (Klauer, 1989; Klauer & Phye, 1994), the domain of inductive reasoning consists of six closely related paradigms, or general reasoning structures. These include generalization, discrimination, cross-classification, recognizing relationships, differentiating relationships, and system construction. Training in the application of these reasoning structures is said to result in "paradigmatic transfer," whereby a reasoning structure is successfully used as a tool for problem solving with content from different situations.

Cognitive Training for Children (CTC) is a developmental program. The initial lessons were designed to be used with children as young as 5 or 6 years, with an increase in lesson difficulty at the advanced level. It can be used as a supplement in the classroom to help students who have difficulty in problem solving or as an assessment tool to measure students' inductive reasoning skills. The success of the CTC program for both regular classroom students and those with learning disabilities has been evaluated by a number of internal evaluations conducted by the original research team and external studies conducted by other authors. With few exceptions, there is overwhelming evidence that the program is indeed effective in improving the problem-solving abilities of trained children (Hager & Hasselhorn, 1998; Klauer & Phye, 1994; Klauer, Willmes, & Phye, 2002; Roth-van der Werf, Resing, & Slenders, 2002).

A Definitional Model of Inductive Reasoning

The practice materials used for the CTC program were generated using the following definitional model for inductive reasoning (Klauer & Phye, 1994). The definition accounts for the operations as well as the content of inductive reasoning. It precisely specifies the thinking processes that distinguish between inductive and other types of reasoning.

The definitional model of inductive reasoning is stated in the form of an incomplete mapping sentence. It contains 3 facets (A, B, and C) with 3, 2, and 5 distinct elements, respectively. Therefore, 3*2*5=30 different types of inductive reasoning problems can be created. As can be seen in Figure 1, inductive reasoning is a process of detecting regularities and irregularities by finding out (A) similarities and/or dissimilarities of (B) attributes or relations with content that are (C) words, pictures, figures, numbers, etc.

Inductive reasoning consists of detecting regularities
And irregularities by finding out

A: { a_1 similarity; a_2 dissimilarity; a_3 similarity & dissimilarity } of B: { b_1 attributes; b_2 relations }

C: with { c_1 verbal; c_2 pictorial; c_3 geometric-figural; c_4 numerical; c_5 other } materials

Figure 1. Definitional Model for Inductive Reasoning

Facet A is the Comparison component. It determines whether one has to look for similarities, differences, or both similarities and differences when making a comparison. Regularities are revealed only when one pays close attention to similarities and differences. Facet B designates the Elements to be compared. It specifies that comparisons are made specifically on attributes or relations, rather than globally based on objects as a whole. Facet C is the Material facet that identifies five classes of materials that could be used to develop a problem. Depending on the purpose, facet C can be constructed according to school subjects such as mathematics or language. Specifically, there are four classes (verbal, pictorial, geometrical-figural, and numerical) plus one non-specific class. These five classes were used in the training program because they occur frequently in tests of cognitive aptitude (Klauer & Phye, 1994).

Facet A and B are the central components of inductive reasoning. They explain six basic types of inductive reasoning tasks that correspond to the six processes that constitute inductive reasoning. The names of the six basic processes and the interrelationships among them are depicted in Figure 2.

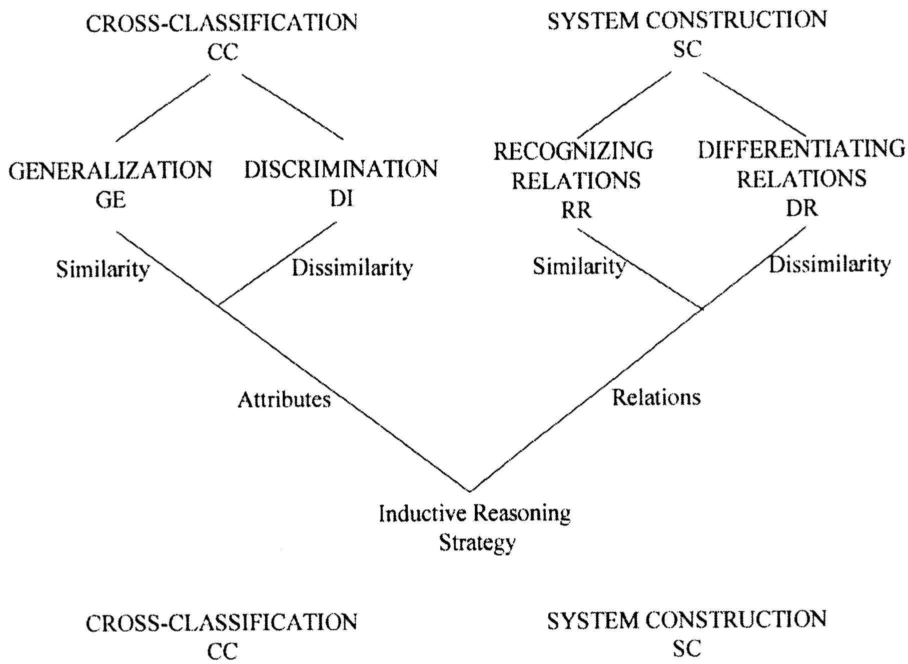

Figure 2. The Genealogy of Tasks in Inductive Reasoning

The left branch of the "family tree" in Figure 2 contains the three inductive tasks that require the processing of surface information about the attributes: Generalization (GE), Discrimination (DI), and Cross Classification (CC). GE is the process of recognizing the similarities of attributes of objects, DI is the process of recognizing the differences of attributes among objects, and CC requires identification of both similarities and differences in attributes. The right branch of the "family tree" refers to the three inductive reasoning processes that are characterized by making comparisons of the relationships among objects, or structural elements: Recognizing Relationships (RR), Discriminating Relationships (DR), and System Construction (SC). RR is the process of recognizing the similarity of relationships, DR is the identification of differences in relationships, and SC requires identification of both similarities and differences in relationships.

According to this definitional model, the cognitive processes of inductive reasoning are defined by the thinking operations employed during reasoning. All inductive reasoning tasks can be solved by first considering the similarity and difference of either attributes or relationships. Therefore, teaching young children to use the meta-cognitive strategy of making analytical and systematic comparisons lies at the heart of the CTC training program (Klauer & Phye, 1994).

1.2 The Web-based Version of "Cognitive Training for Children"

In the past ten years, there has been a dramatic increase in the development of computer and Internet technology which has impacted the landscape of traditional classroom instruction. In particular, the World Wide Web is increasingly being used as a means for delivering instruction because of the amount and interactive nature of information that is available at low cost. Web-based programs can also easily integrate multimedia such as graphics, sound, and animation (Verrest, 2000).

Educators at all levels are increasingly supplementing their instruction with web-based technologies. This may include helping students conduct research on-line, putting course materials and assignments on the web, or conducting virtual simulations. Some courses are even delivered on-line without face-to-face interaction. Computer-based technology also has wide application in assessing students' problem-solving abilities (Baker & Mayer, 1999).

A web-based version of the *Cognitive Training for Children* (WCTC) program was developed by Verrest (2000). The overall goal of the WCTC program is to teach 4th grade students who have difficulty in acquiring skills for fractions through regular classroom instruction how to solve fractions problems by using inductive reasoning skills. The development of the WCTC program was based on theories of inductive reasoning and problem-solving transfer, as well as principles of usability. Specifically, the developer used: 1) document analysis of human factors knowledge and design guidelines; 2) information provided by 4th grade teachers regarding the prospective users of the WCTC program and the context in which the program is used; and 3) feedback provided by 4th grade students who tested the prototypes of the WCTC program. The WCTC has been labeled as a usable application after an examination of usability issues such as learnability, efficiency, errors, and satisfaction (Verrest, 2000).

WebCT, which was developed at the University of British Colombia, was chosen as the tool for the development of the WCTC program. WebCT requires minimal technical expertise on the part of the designer as well as the student. In addition, the program incorporates both a set of administrative tools and educational tools, such as quizzes, to assist the instructor in managing student performance and participation (Wang, 2004).

The WCTC program was designed to teach 4th grade students to solve fraction problems using the cognitive strategies of inductive reasoning, as well as the meta-cognitive strategies of monitoring understanding. The program contains 52 different fraction problems and is divided into three parts: Introduction, Lessons, and Extra Quizzes. The Introduction helps students identify the differences between *characteristics* (attributes) of the objects and *relationships* among objects through two examples of each. The first example of the two is object-based and the second is fraction-based. The factual or conceptual (declarative) knowledge about characteristics of objects, relations between objects, and similarity and dissimilarity is explained to the child in the Introduction phase. As a result, the child knows that objects can share similar attributes and pairs of objects can share common relations.

The Lesson section contains six lessons, each ending with a 10-problem quiz. Table 1 provides an overview of the format in terms of basic types of reasoning processing procedures, the types of problems (object or fraction-based), and the order of the presentation for examples within each lesson.

Table 1. Overview of the Format of the WCTC Program

Lesson		GE	DI	CC	RR	DR	SC
1	Example	1O(1) 1F(2)			1O(3) 1F(4)		
	Quiz	5F			5F		
2	Example		1O(1) 1F(2)			1O(3) 1F(4)	
	Quiz		5F			5F	
3	Example			1O(1) 1F(2)			1O(3) 1F(4)
	Quiz		5F			5F	
4	Example	1F(1)	1F(2)	1F(3)			
	Quiz	3F	4F	3F			
5	Example				1F(1)	1F(2)	1F(3)
	Quiz				3F	3F	4F
6	Quiz	1F	2F	2F	1F	2F	2F

Types of problems: O = Object-based problems; F = Fractions problems
Order of the presentation for examples within each lesson is provided in parentheses

As can be seen in Table 1, Lessons 1 to 5 contain three or four examples as well as a quiz, where examples provide the study episode and quizzes provide the practice episode. Lesson 6 contains only a quiz. The first three lessons provide study and practice for all six basic types of inductive reasoning processing, with each lesson focusing on two types. The examples requiring common reasoning processing are grouped together within each lesson. The last three lessons provide recursive reintroduction of all six types of inductive reasoning processing. The problems are arranged to be consistent with transfer-appropriate processing and transfer-appropriate models.

The complexity of the presented examples increases as a student progresses through the six lessons. This was accomplished by manipulating the types of examples. In the first three lessons, examples are object-based as well as fraction-based. The object-based examples of the procedures always precede the fraction-based example of that same procedure to facilitate learning. Use of concrete symbols, such as objects, should help students understand how to solve certain problems more easily. Then, after the general idea is clear, students practice with an abstract fraction-based example, which should further prepare them for the quiz.

The instruction placed on the top of each WCTC example page is important in training. It helps children clearly identify and state the problem, tells them that inductive reasoning problems typically require the analysis of similarities and differences, helps them develop a solution strategy as well as a monitoring (meta-cognitive) strategy based on the analysis of similarities and differences, and teaches them how to recognize the problem type and associate it with a paradigm being trained. Here is an example of the instruction for the problem about placing items in order based on their relationship:

"The second type of problem in this lesson looks at what happens between the items in a puzzle. The same thing happens between the items.

To solve this type of problem, you have to look for what happens between the items. For example, the items can be organized by size or number. When you find what happens between the items, you can answer questions that ask you to place items in the appropriate order or questions that ask you to add the item that would come next.

When you think you know the answer, check if the same relationship exists between all items in the pattern you created. Only then you know if you are correct or not!"

The problem type (placing items in order) and solution strategy (seeking similarity of relationships) are elaborated to children in the instruction. A reverse check is taught as a meta-cognitive monitoring strategy to help students check their answer. Corrective feedback in the form of an answer and explanation are contained in the paragraph below the problem. For this problem, the correct answer is, "The geese are related to each other by size. You can place them in order from small to large, BDACE, or from large to small, ECADB." By practicing this example, children learn the particular process of recognizing relationships. To help students understand how such problems are "represented" in memory, the instruction also associates the problem type of "placing items in order" with the process of "finding what happens between the items" (recognizing relationships). A summary of the problem types used in the WCTC program and the representative cognitive operations as well as monitoring strategies is presented in Table 2.

Table 2. Inductive Reasoning Processes with Respective Problem Types in the WCTC

Processes	**Question Type**	**Cognitive Operation**	**Reverse Check**
GE	Grouping items	Similarity of characteristics	If the other items don't have the characteristic one selected
DI	Finding the item that doesn't belong in the group	Difference of characteristics	If the items that are left all have the same characteristic
CC	Replacing one item with another	Similarity and difference in characteristics	If the item that one had to place in the square doesn't have the same characteristic as one of the items in the other squares
RR	1. Placing items in an appropriate order 2. Adding the item that would come next 3. Selecting an item which would fit in the group	Similarity of relationships	If the same relationship exists between all items in the pattern one created
DR	Finding the item that doesn't fit in the pattern or messes up the order	Differences of relationships	If the same relationship exists between all items left after one takes away the item that didn't fit
SC	Placing an item in the empty square	Similarity and difference of relationships	If the same relationship exists between the items in the top row and bottom row and between the left column and right column

Examples of similar processing are repeated in quizzes. The repetition provides an opportunity for the development of strategic knowledge. By doing quizzes, children store procedures and strategies into long-term memory and spontaneously retrieve them as prior knowledge when encountering a new problem. In addition, the identification of problem types and the respective solution procedures also promotes the development of strategic knowledge.

Students' performance on the quizzes is recorded automatically by the computer. A results page that contains corrective feedback is available for students after they submit each quiz for grading. The corrective feedback provides a study episode for students. Quiz performance is used to estimate of the development of students' inductive reasoning abilities when solving fraction problems.

1.3 Pilot Study

Recently, a pilot study was conducted to assess the educational effectiveness of the Web-based Cognitive Training for Children (Wang, 2004). Two major questions were addressed: 1. Does training using the WCTC significantly improve students' performance in problem-solving tasks with fractions? 2. What are the comparative effects of training for students who are identified as low and high performers based on pretest results?

Participants in the study were two fourth grade classes. Classes were randomly assigned to either experimental or control conditions. The experimental group received training in inductive reasoning as applied to fraction problems using the WCTC, where as the control group practiced fractions using educational web sites. A pretest-posttest design was used to measure the effects of training (Wang, 2004).

The results of this pilot study indicated that the WCTC program was effective in improving performance for 4^{th} grade students who were identified as low performers with fractions. That is, students in the training group who were identified as low performers made significantly greater gains from pretest to posttest than their counterparts in the control group.

The results also indicated that low performers gained significantly more than high performers in the training group, and no differences were observed between low and high performers in the control group. However, the improvement differences between the training group and control group were not significant. The researcher concluded that the WCTC program was effective in improving low performers' fractions skills, although it was not effective for the whole class (Wang, 2004).

The researcher identified several problems that served as limitations in the pilot study, ranging from technical problems with the WCTC program and available computers, to a small sample size of only 39 students. The current investigation was conducted in an attempt to address these concerns and verify the reliability of the pilot study.

One problem experienced in the pilot study was the WCTC program's inability to detect all correct answers given by students on the quizzes. For example, when students were asked to group similar items, responses of abc, acb, bac, bca, cab, and cba would all represent the same group. Therefore, each of them should be the correct answer. The designer of the program has taken this issue into consideration and made the program accept all types of correct answers due to permutation. However, some students put a comma or space between the letters that represent a whole group, and the computer did not give them credit for their correct answer. This led to confusion on the part of students as they read the corrective feedback (Wang, 2004). This problem was addressed in the current study by changing the setting and amount of instruction. The educational intervention was conducted in a computer lab where the researcher could provide direct instruction in how to answer the questions to the whole group at once. Examples were provided in how to type in the answers so that the computer would give them credit for a correct response.

Another technical problem identified in the pilot study concerned the lack of available memory on the computers used (Wang, 2004). Some of the computers froze up after students completed the quiz. This created added frustration for students who had to restart the computer, scroll back through the lesson, and then retake the quiz. Students' need for technical assistance was very high and only the classroom teacher and investigator were available to help. In the current study, different computers were used and another adult was available to provide technical assistance.

The final modification in the current study concerned the fractions test used as a measure of problem-solving transfer. The pre- and posttest measures used in the pilot study to assess fractions knowledge were traditional paper-and-pencil tests composed of 30 multiple-choice fractions problems. Twenty questions on each test were from the test materials contained in the 4th grade textbook series used by the participating school district, and ten questions were created by the investigator to increase the test difficulty and avoid a ceiling effect. However, the types and format of the 10 added questions were similar to the 20 from the textbook series (Wang, 2004).

The federal No Child Left Behind Act of 2001 requires that educational practitioners use "scientifically-based research" to guide their decisions concerning programs to be implemented in the school curriculum. "Only those strategies and methods proven effective by the standard of scientifically based research should be included in school reform programs," (*Scientifically based research and the Comprehensive School Reform (CSR) Program*, 2002). For the WCTC to be considered an effective educational intervention, the program must be supported by rigorous empirical evidence. One of the keys in establishing "strong" evidence of effectiveness is that the program must significantly improve student academic achievement.

Two recent publications give indications of how to measure improved academic achievement. According to *Scientifically based research and the Comprehensive School Reform (CSR) Program* (2002), studies must show gains on a norm-referenced, standardized test in order to have educational, or practical, significance. Also, the Coalition for Evidence-Based Policy states in its 2003 publication,

> "The study should use outcome measures that are 'valid' – i.e. that accurately measure the true outcomes that the intervention is designed to affect. Specifically, to test academic achievement outcomes, a study should use tests whose ability to accurately measure true skill levels is well-established." (p. 6)

According to these definitions, it is difficult to assume that a fractions test written by textbook publishers would qualify as rigorous evidence of student academic achievement. Therefore, a different instrument to measure problem-solving transfer as it relates to fractions was needed for the current study. A description of the pre- and posttest instrument can be found below in the methods section.

1.4 Problem Statement

The WCTC program has been examined in terms of its technical usability. However, researchers have only just begun to investigate its instructional effectiveness in improving 4th graders' problem-solving abilities with fractions. This study is to investigate the instructional effectiveness of the WCTC program as an educational intervention. More specifically, it attempts to answer the question, "Do 4th grade students who receive training with the WCTC program have significantly greater gains than untrained students in fractions performance?"

In addition, this study investigates the comparative effects of the WCTC program on students who initially are at different performance levels. Researchers have investigated the effectiveness of the CTC program on students at various intelligence levels, and found that mentally retarded and gifted students benefited from the CTC program as well as normal students (Hager & Hasselhorn, 1998; Klauer & Phye, 1994). Also, in a pilot study by Wang (2004), the WCTC was shown to be more effective for regular students who were low performers on fractions problems than for high performers. This study attempts to further investigate those findings by dividing subjects into three groups (low, medium, and high) based on their initial fractions performance.

1.5 Purpose of the Study

The purpose of this study is to further evaluate the effectiveness of the WCTC in improving 4th grade students' performance in fraction problems by addressing concerns raised in the initial pilot study. In addition, this study attempts to investigate the comparative effects of the WCTC program with students who are identified as low, medium, and high performers.

It is expected that the information gained in this study will provide empirical evidence concerning the effectiveness of the WCTC program as an educational intervention, which may serve as the basis for further modification to the program and/or support for its use in the educational setting. It is also hoped that this study will add to the body of knowledge regarding the central role of inductive reasoning in problem solving.

1.6 Human Subjects Release

The Iowa State University Committee on the Use of Human Subjects in Research reviewed this project in an effort to ensure that the rights and welfare of the human subjects participating in the study are adequately protected. They concluded that no physical or emotional risks were present, that confidentiality was assured, that informed consent was obtained by appropriate procedures, and that potential benefits and expected value of knowledge sought were acceptable.

CHAPTER 2: METHODOLOGY

2.1 Participants

The study was administered in a Midwest elementary school with six 4th grade classes. The district administrators and teachers of the selected classes agreed to participate. Parents signed a Parental Consent Form to grant permission for their child to participate, and students signed a simplified version of the informed consent document to agree to be in the study.

The computerized program required a great deal of independent reading for instructions and corrective feedback. Students with severe reading and/or learning disabilities would not be able to complete the program independently. Therefore, these students, as indentified by information contained in their Individual Education Plan, were excluded from the subject selection. As a result, a total of 143 students served as participants.

2.2 Experimental Design

A block randomization design was used to assign classes to treatment or control conditions based on an analysis of the class mean math total score on the Iowa Tests of Basic Skills. A one-way ANOVA showed no significant difference in general math achievement between classes, $F(5,137) = .750, p = .588$. The two classes with the highest scores were randomly assigned to treatment or control, as were the middle two classes, and the two lowest scoring classes. The experimental group consisted of 73 students, and the control group contained 70 students.

Since most problems contained in the WCTC program are based on fractions, participants must have some knowledge of fractions to use it. The study was implemented after the fractions instruction provided by the regular classroom teacher.

Pretest

The pretest is a form of a traditional paper-and-pencil test, and is comprised of 15 questions. (See Appendix A.) The problems are NAEP - released items relating to fractions, all of which appeared on a NAEP exam within the past 20 years (*National Center for Educational Statistics, National Assessment of Educational Progress (NAEP)*). They are a mix of multiple choice and constructed response items. Most of the questions are 4th grade items, although four questions were taken from the 8th grade test in order to avoid a ceiling effect. All questions are classified by NAEP in the mathematical content area of Number sense, Properties, and Operations. Questions cover a mixture of all three types of mathematical ability: conceptual understanding, procedural knowledge, and problem solving. The test was scored according to the guidelines provided by NAEP.

Participants were given a pretest after their regular fractions instructional unit, so that the pretest provides an estimate of students' knowledge about fractions prior to training. Participants were identified as high, medium, or low performers based on their pretest performance.

Training

Treatment Group. The training began within a week after the pretest. Participants in the treatment group received the WCTC training on the computer over two or three successive days, approximately one hour per day. They were required to finish 6 lessons with quizzes individually and control the pace themselves. It took students an average of about 20 minutes to compete each lesson with a quiz.

In the beginning of the training, the investigator reminded students to read the instruction before solving problems, do the quiz after each lesson, and read the feedback for their solutions. Students' performance on the quizzes was recorded on-line automatically.

Control Group. During the training, participants in the control groups "played" with some web-based fractions games. (See Appendix B for the list of fractions web sites.) Following a short period of instruction in which the directions of each game were explained, students in the control group worked through the web site independently. No inductive reasoning strategies were taught or explained in these games. Participants were given one hour per day over two successive days to play with the fractions games. Therefore, the duration of implementation in the control group was similar to the average duration in the training group.

Posttest

All participants were given a posttest one week after training. The test was administered in the regular classroom by the classroom teacher. The same 15 questions were used for the posttest as were used on the pretest. In keeping with practices common to the study of strategic transfer, no reference was made to prior training and practice. Students' performance on the posttest was viewed as an estimate of strategic transfer.

2.3 Hypotheses of the Study

Two main research hypotheses were evaluated in this study. The first hypothesis relates to the effectiveness of the WCTC program. It is expected that students who receive the WCTC training will show greater improvement than students who are in the control group from the pretest to posttest. Hypothesis 2 investigates the comparative effectiveness of the WCTC program for students who are identified as high, medium, and low performers. It is expected that low and medium performers will have significantly greater gains than high performers in the training group.

CHAPTER 3: RESULTS

The pretest and posttest were scored according to NAEP guidelines and expressed in terms of points earned. The highest score possible for both tests was 22 points. Data were analyzed using the Statistical Package for the Social Sciences (SPSS).

3.1 Hypothesis Concerning Effectiveness of the WCTC Program

According to research hypothesis 1 it was expected that the WCTC program would be effective in improving 4th grade students' performance in fractions. Therefore, it was expected that the training group would demonstrate greater improvements than the control group from pretest to posttest. Descriptive statistics for the two groups over time are given in Table 3.

Table 3. Means and Standard Deviations of the Two Groups and Tests

Group		**Pretest**	**Posttest**
Training Group	Mean	9.32	11.64
(N=73)	SD	3.39	3.85
Control Group	Mean	10.71	12.00
(N=70)	SD	3.62	3.64

By looking at the pretest scores, one can see that the training and control group differed from each other prior to training. The control group yielded higher scores on the pretest, and this difference was statistically significant ($t = 2.369$; $p = .019$).

An analysis of covariance was used to test the mean difference between training and control groups on the posttest, with the pretest score used as a covariate. A significant main effect of Group was found, $F(1,139) = 5.636$; $p = .019$. The adjusted means of the posttest scores were calculated while controlling for pretest performance. The adjusted means are as follows: Treatment $M_{adj} = 12.289$; Control $M_{adj} = 11.389$. Although initially the training group had a slightly lower (-.36) mean posttest score, after controlling for pretest performance, the training group had an average posttest score that was nearly 1 point higher than the control group.

Classes were assigned to treatment and control conditions using a block randomization design, based on an analysis of math achievement as measured by the Math Total scores on the ITBS. A one-way ANOVA of class differences yielded a non-significant result. However, an analysis of the pretest scores by class does show a significant difference, $F(5,136) = 2.567$; $p = .030$, with the greatest difference occurring between Class B and Class C. This mean difference was detected as significantly different using Bonferroni's post-hoc test for multiple comparisons ($p = .027$). There were no other significant comparisons by class.

Since there was a class effect on pretest scores, the analysis of covariance was rerun using class as the error term. These results failed to reach statistical significance, $F(1,4) = 2.45$; $p = .19$. This result was affected by the fact that there were only six classes participating in the investigation. Since the df = 4 for the error term, there was much less power in this latter analysis.

Although the effectiveness of the WCTC program did not reach statistical significance, effect size measures were still calculated according to Cohen's d. Since there was a pretest difference between the training and control groups, a corrected effect size (d_{corr}) was calculated using the adjusted means. In this calculation, $d_{corr} = (M_{TG} - M_{CG})/s_p$, where s_p is the pooled standard deviation. As a result, a small to moderate effect size of .237 was obtained.

Another way to investigate the comparative improvement of the training and control groups is to examine the improvement scores for each group. The improvement score was calculated by taking posttest – pretest for each student. The average development of fractions performance by group is represented graphically in Figure 3.

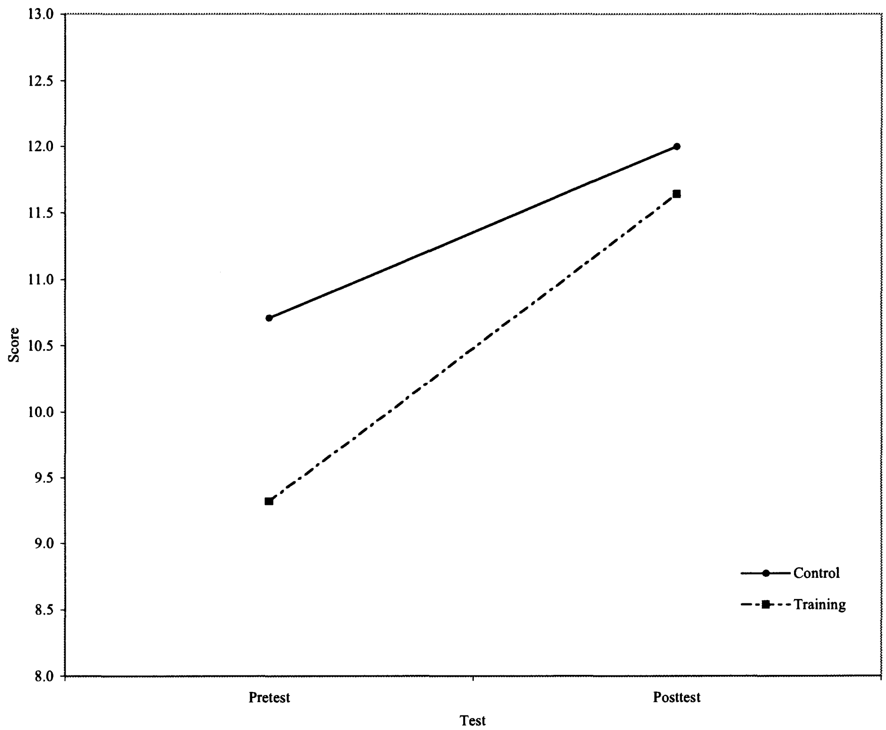

Figure 3. Development of Fractions Performance of the Two Groups

As depicted in the graph, the average improvement for the treatment group was 2.38 points (SD = 2.388), where as the control group had an average improvement of 1.29 points (SD = 2.114). An independent t-test of the mean improvement score by group yielded a significant difference ($t = -2.875, p = .005$).

Since the pretest scores of the treatment and control groups were different, and the treatment group showed significantly more improvement after intervention, the posttest scores were examined to see if there was still a significant difference between groups. An independent t-test showed that the difference in group means was no longer significant ($t = .568$, $p = .571$).

Figure 4 depicts graphically the pretest and posttest scores for the six classes and is organized by treatment condition. As can be seen in the graph, two training classes (Class A and Class D) showed great improvement from pretest to posttest, with average improvements of 2.83 points and 2.96 points, respectively. By contrast, Class B had an average increase of only 1.4 points. Further investigation of Class B's scores appears to be warranted.

Taken together, the results indicate that there were greater gains for students who received training with WCTC program than for the control group, as was predicted in hypothesis 1. However, since there was a class effect on the pretest, the results are influenced by the relatively small number of classes.

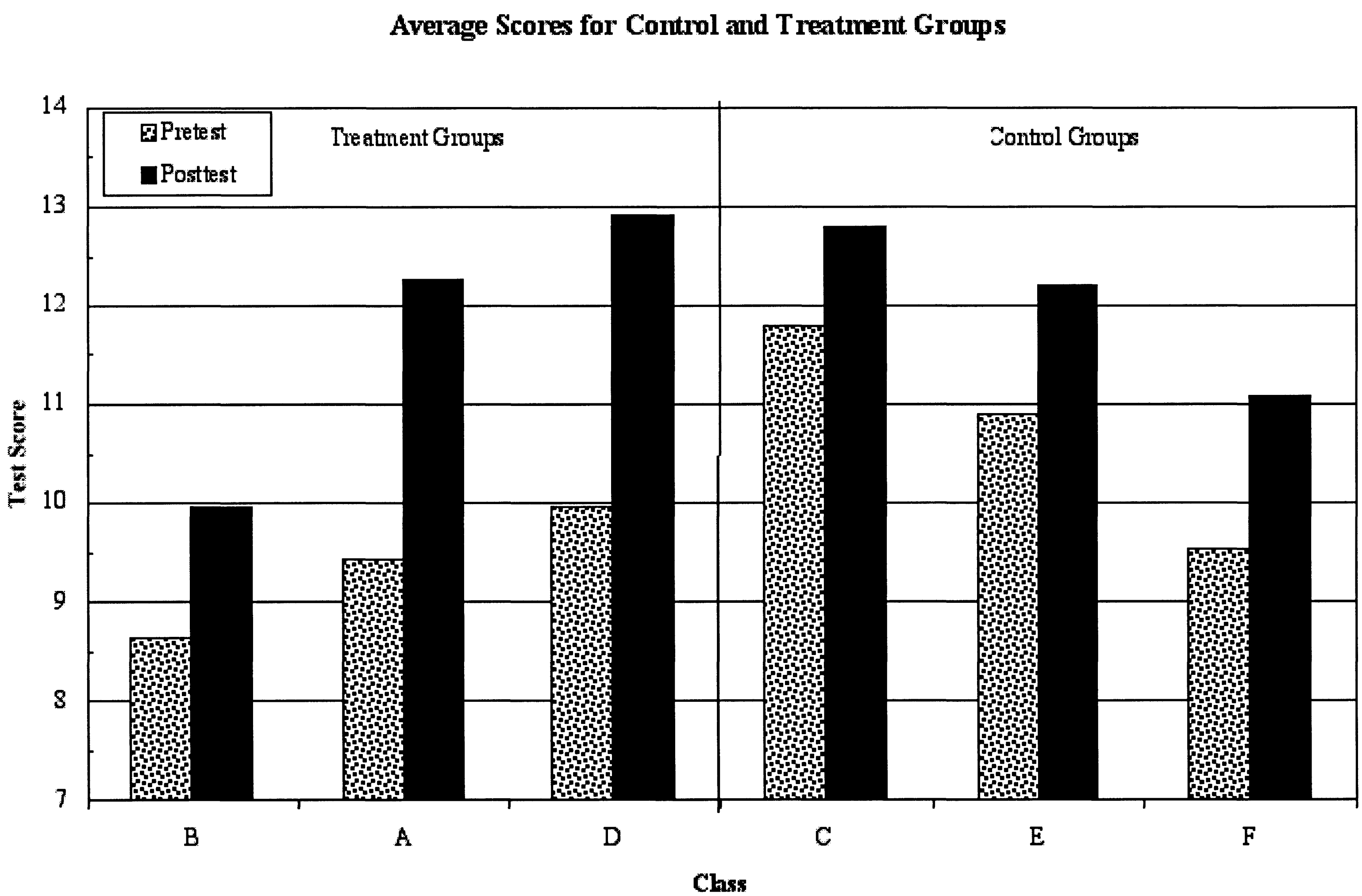

Figure 4. Average Scores by Class on pretest and posttest

3.2 Hypothesis Concerning the Comparative Effects of the WCTC Program on Low, Middle, and High Performers

With research hypothesis 2, it was expected that there would be a difference between low, middle, and high performers in the effectiveness of the WCTC program to improve fractions performance. Using a frequencies analysis, both groups were divided into three sub-groups (low, middle, or high performance level) based on students' fractions performance on the pretest. In Table 4, the means and standard deviations of the three sub-groups are presented for both groups and both tests.

Table 4. Means and Standard Deviations of the Performance Sub-groups for Both Groups and Both Tests

	Pretest		**Posttest**		**Improvement**	
Training	Mean	SD	Mean	SD	Mean	SD
Low (N=31)	6.32	1.76	9.16	3.38	2.84	2.73
Middle (N=23)	9.87	.82	12.22	1.91	2.35	1.80
High (N=18)	13.78	1.96	15.39	3.24	1.61	2.33
Control						
Low (N=21)	6.76	1.26	9.10	2.26	2.33	1.85
Middle (N=22)	10.05	.79	10.77	2.49	.73	2.66
High (N=27)	14.33	2.56	15.26	2.68	.93	1.49

Figure 5 presents the development of fractions performance for low, middle, and high performers in the training and control group. As one can see, there were considerable gains for all three performance groups in the training condition, where as only the low performers had sizable gains in the control group. A series of independent sample t-tests were conducted for each of the three performance groups (low, middle, and high) to compare the mean improvement scores of training vs. control groups. For the low performance group, $t = -.739$ ($p = .463$); for the middle performance group, $t = -2.405$ ($p = .021$); and for the high performance group, $t = -1.106$ ($p = .279$).

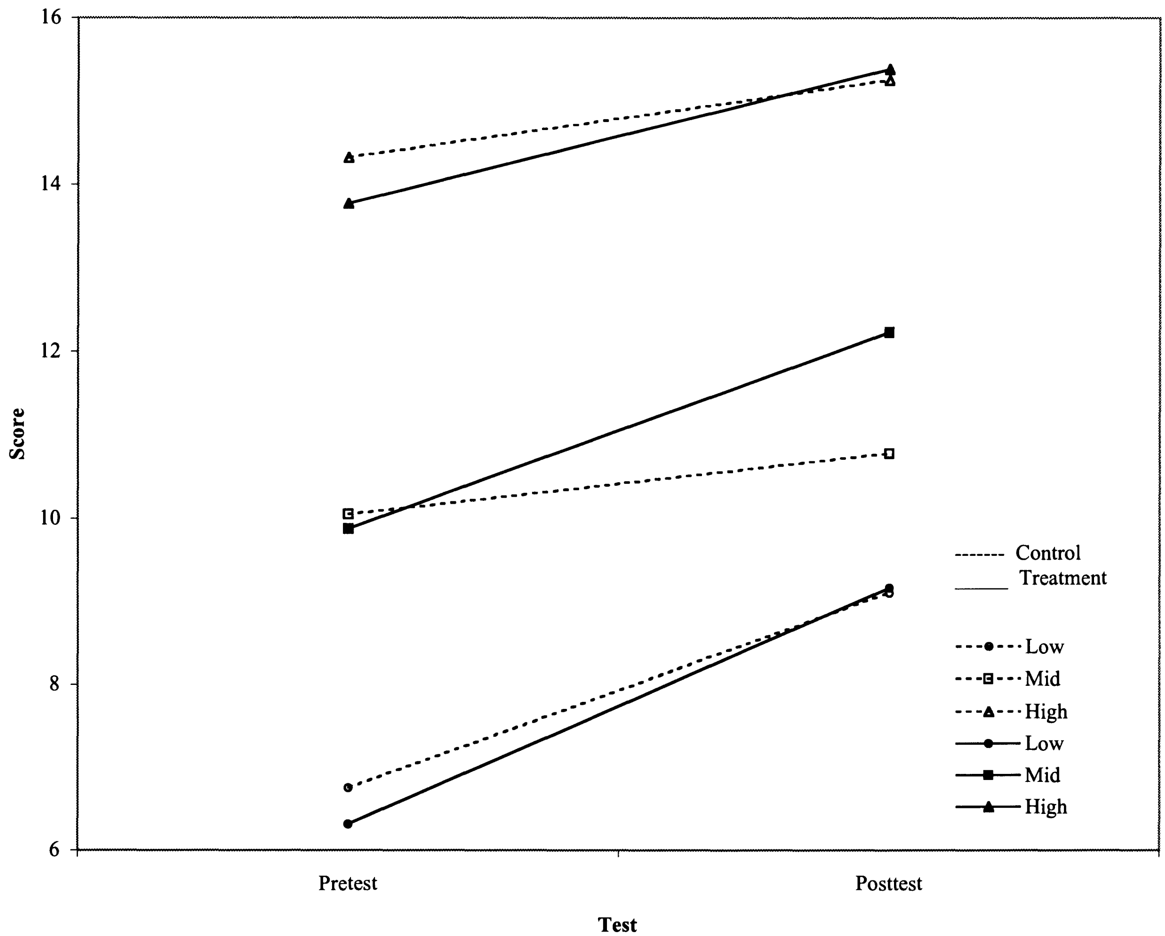

Figure 5. Development of Fractions Performance for Low, Middle, and High Groups

To test the gain differences of the three groups another way, an analysis of covariance (ANCOVA) was conducted for each performance group using posttest scores as the dependent variable, group (treatment or control) as the independent variable, and pretest scores as a covariate. Once again, only the middle performance group showed a significant result, F (1,44) = 5.080, p = .029. The effect sizes of this analysis tell a similar story: for the low performance group d_{corr} = .187, for the middle performance group d_{corr} = .652, and for the high performance group d_{corr} = .230.

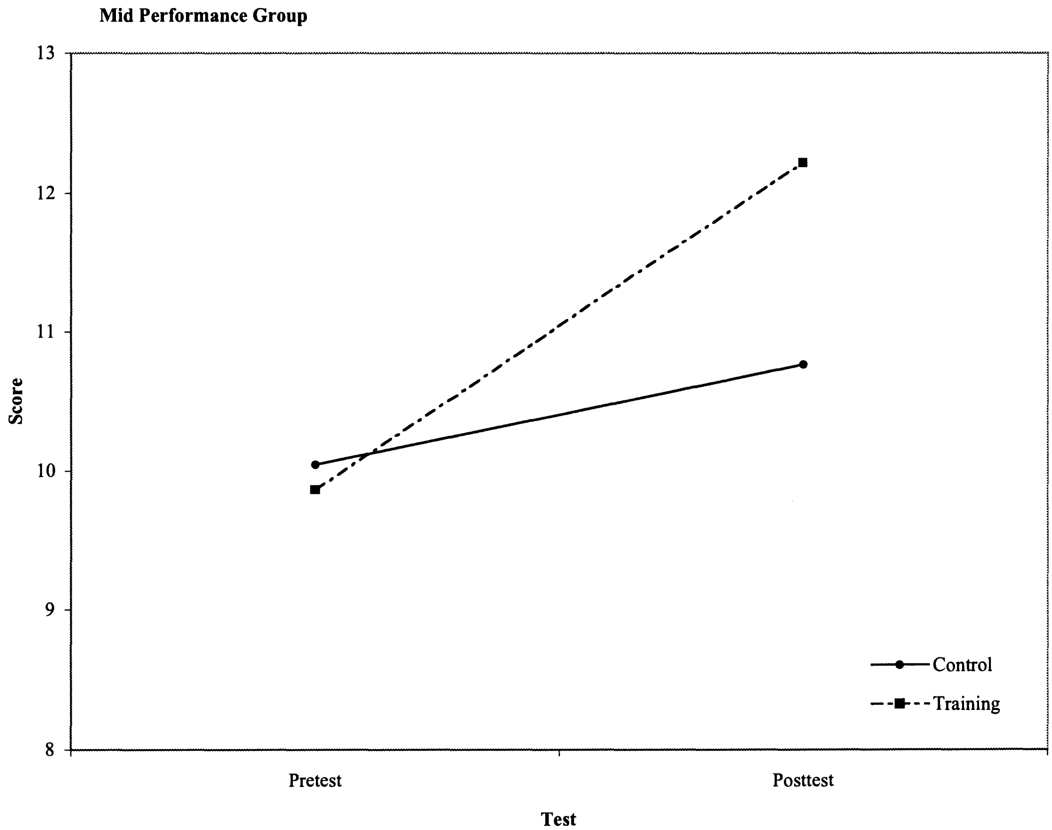

Figure 6. Development of Fractions for Middle Performance Group

One can see that for the middle performance group, those who received the training had a negligible lower score (-.18) than the control group on the pretest. On the posttest, the mean difference increased to +1.45 points because of greater gains for the training group. Therefore, it can be concluded that the WCTC program was most effective for the middle performance group. Based on these results, hypothesis 2, that the WCTC program would be more beneficial for low and medium performers, was partially supported.

3.3 Readability of the "Web-based Cognitive Training for Children"

To determine what, if any, effect students' reading ability had on their success with the WCTC program, the readability of the WCTC was examined. Using Fry's Readability Formula (Fry, 1977), seven 100-word samples of text were analyzed according to the number of sentences and syllables per passage. The readability of the passages ranged from 5th grade level to 7th grade level, with most passages scoring in the 6th grade range. The passages had an average of 134 syllables and 7.3 sentences, which yields an approximate readability at the 6th grade level.

Students' reading achievement was determined using scores on a standardized achievement level test administered by the participating school district. A one-way ANOVA of reading test scores yielded a significant difference between classes, $F(5,137) = 2.275$, $p = .050$. As can be seen in Table 4, Class B had the lowest average scores on both tests of reading achievement. However, when correcting for the Type 1 error rate using Bonferroni's post hoc test of multiple comparisons, no significant differences were detected.

Table 5. Average Reading Achievement by Class

Class	**Achievement Level Test RIT Score**		**Iowa Tests of Basic Skills Standard Score**	
	Mean	SD	Mean	SD
A	209.42	8.005	216.52	25.118
B	203.50	9.929	207.96	23.765
C	209.08	11.613	216.38	26.035
D	207.13	8.198	215.61	24.100
E	211.61	8.447	222.14	22.375
F	204.36	13.089	209.53	22.121

Students' success in using the WCTC program was measured by their performance on six quizzes of 100 points each. A Quiz Total score was calculated for each student by adding the six separate quiz scores. A Pearson product-moment correlation showed a significant positive relationship between quiz total and reading achievement, r = .691, $p < .001$. In other words, students with higher reading achievement scores tended to score more highly on the WCTC quizzes.

Another way to test this relationship was through an analysis of variance (ANOVA) on quiz performance by reading proficiency level. Students were assigned a proficiency level based on their performance on the standardized achievement level test. In keeping with NCLB and ITBS designations, students with scores below the 40th percentile were categorized as "below proficient", students with scores between the 40th and 90th percentiles were categorized as "proficient", and students with scores at or above the 90th percentile were deemed to be "advanced." A one-way ANOVA revealed a significant difference between groups on the WCTC quizzes, $F(2,68) = 19.043, p < .001$. According to Bonferroni's post hoc test of multiple comparisons, all possible comparisons were statistically significant. The results can be seen in the table below.

Table 6. Multiple Post-hoc Comparisons

Bonferroni		**Mean Difference (I-J)**	**Std. Error**	**Significance**
(I) RDGPROF	(J) RDGPROF			
Below Proficient	Proficient	-72.89*	14.299	.000
	Advanced	-146.73*	30.633	.000
Proficient	Below Proficient	72.89*	14.299	.000
	Advanced	-73.84*	29.877	.048
Advanced	Below Proficient	146.73*	30.633	.000
	Proficient	73.84*	29.877	.048

* *The mean difference is significant at the .05 level*

The bivariate correlation and ANOVA results taken together suggest that reading achievement plays a significant role in a student's ability to perform well on the WCTC.

When comparing the reading achievement of just those classes who received the training in inductive reasoning, a one-way ANOVA approached significance, $F(2,70) = 2.886$, $p = .062$. Class B, which had less proficient readers (seen in Table 4), also had lower average scores on the WCTC quizzes.

Table 7. Average Total Score on the WCTC Quizzes

Treatment Classes	Mean	SD
Class A	262.92	58.05
Class B	233.46	82.36
Class D	259.52	65.23

Finally, when comparing just the three classes in the training group, there was no significant difference in pretest performance between these classes, $F(2,69) = .916$, p =.405. However, there was a significant difference in their posttest performance, $F(2,70) = 4.423$, $p = .016$. All three classes received the same intervention between tests. Taken together, these results seem to suggest that the lower reading achievement of Class B had a negative impact on the students' problem-solving abilities as measured on the posttest.

3.4 Analysis of Test Instrument

A reliability analysis was conducted on the test items for the pretest and posttest measures in order to assess the internal consistency of the items. Since the test items had all been previously used on a NAEP test, it was assumed that reliability analyses had already been conducted on the items prior to their appearance on a national assessment. However, this is the only known instance where these 15 particular items appeared together on one assessment.

A coefficient alpha was calculated for both the pretest and posttest. For the pretest, $\alpha = .5870$, and on the posttest, $\alpha = .6179$. For both tests, the reliability coefficient was higher if test item #4 was discarded. These relatively low coefficients were probably influenced by several factors. First, the test contains a small number of items. Tests with a larger number of items will have a greater reliability. Second, this test contains heterogeneous tasks, with questions measuring several different aspects of problem solving with fractions. In this case, the coefficient alpha can be considered a lower-bound estimate of reliability (Nitko, 2004).

National performance results were reported for each test item when the test was administered by NAEP (*National Center for Educational Statistics, National Assessment of Educational Progress (NAEP)*). Results were given as a percentage of students who answered the question correctly, incorrectly, or omitted the item. This allows for a comparison of subjects' scores to performance on a standardized test. The results and comparisons for both control and treatment groups are displayed in Table 8 below.

Further analysis was conducted for each test item to determine if the group's posttest performance was significantly higher than pretest performance using a series of pairwise comparisons of means. Both control and treatment groups showed significant improvements on question #6 (Control: $t = -3.628$, $p = .001$; Treatment: $t = -4.633$, $p = .001$) and on question #8 (Control: $t = -2.990$, $p = .004$; Treatment: $t = -4.605$, $p < .001$). In addition, the control group showed significant improvement from pretest to posttest on question #9

(t = -2.189, p = .032). Finally, there were four other questions where only the treatment group showed significant improvement. These were items #7 (t = -3.540, p = .001), item #11 (t = -3.521, p = .001), item #12 (t = -2.176, p = .033), and item #13 (t = -3.999, p < .001).

Table 8. Test Item Comparisons

			Control		Treatment	
Question #	**NAEP Classification**	**National Results % Correct**	**Pretest Results % Correct**	**Posttest Results % Correct**	**Pretest Results % Correct**	**Posttest Results % Correct**
1	Conceptual Understanding	83%	90%	93%	86%	90%
2	Conceptual Understanding	50%	80%	79%	71%	69%
3	Conceptual Understanding	12%	91%	86%	86%	85%
4	Conceptual Understanding	43%	76%	81%	68%	81%
5	Conceptual Understanding	37%	37%	37%	53%	64%
6	Problem Solving			[2]		[2]
	Extended	19%	20%	31%	18%	43%
	Satisfactory	11%	23%	21%	22%	8%
	Partial	21%	33%	33%	21%	16%
	Minimal	36%	21%	14%	35%	30%
7	Procedural Knowledge	27%	30%	40%	25%	51%[2]
8	Problem Solving			[2]		[2]
	Extended	16%	13%	16%	10%	16%
	Satisfactory	8%	6%	13%	3%	10%
	Partial	2%	1%	3%	1%	4%
	Minimal	18%	37%	50%	31%	44%
9	Conceptual Understanding	35%	34%	49%[3]	49%	51%
10	Conceptual Understanding	65%	21%	26%	17%	14%
11	*(Unavailable)*	64% [1]	40%	41%	17%	40%[2]
12	*(Unavailable)*	64% [1]	20%	20%	3%	11%[3]
13	*(Unavailable)*	11%	90%	93%	63%	84%[2]
14	*(Unavailable)*	24% [1]	13%	16%	17%	23%
15	*(Unavailable)*	35% [1]	19%	14%	8%	14%

[1]*Results for 8th grade students*
[2]*Significant Improvement Pretest to Posttest, p < .01*
[3]*Significant Improvement Pretest to Posttest, p < .05*

CHAPTER 4: DISCUSSION

4.1 Summary

The Web-based Cognitive Training for Children was designed to help improve 4th grade students' problem-solving abilities in fractions by teaching inductive reasoning skills, especially for those who may have difficulty in acquiring skills for fractions through regular classroom instruction. The technical usability of the program was examined by Verrest (2000), and its instructional effectiveness was examined in a pilot study by Wang (2004). The purposes of this study were to further evaluate the effectiveness of the WCTC by addressing concerns raised in the initial pilot study and to investigate the comparative effects of the WCTC program with students who are identified as low, medium, and high performers with fraction problems.

Participants were six 4th grade classes. Using a block randomization design, three classes with 73 students were assigned to the training group to receive training in inductive reasoning skills using the WCTC program, and three classes with 70 students were assigned to the control group to practice fraction problems on educational web sites. The study was implemented after the regular classroom fractions instruction unit. A pretest-posttest design was employed in this study. Participants were identified as high, middle, or low performers based on their pretest performance.

The research hypotheses for this study came from the theoretical basis that inductive reasoning is a central process to higher-order thinking and problem-solving performance, as well as the empirical evidence gained in the pilot study that the WCTC program is more beneficial for low performers with regards to fraction problem-solving. The research hypotheses were:

1. Students who receive the WCTC training will demonstrate greater improvements than those who are in the control group from the pretest to posttest.

2. The WCTC program will be more beneficial for low and medium performing students. Students who are identified as low and medium performers will have significantly greater gains on the posttest than high performers in the training group.

4.2 Conclusions

A statistical analysis comparing posttest results for the training vs. control group controlling for pretest score showed that the training group performed significantly better. However, a one-way ANOVA of pretest scores showed that there was a significant difference among the six classes before the intervention. When the analysis included a component to account for the class effect, the results did not achieve statistical significance. However, the small to moderate effect size of .237 shows that the intervention clearly had an impact in the direction that was expected.

Because of the class differences on the pretest, the training group had a significantly lower average score than the control group. These differences were decreased on the posttest because of greater improvements in fractions performance for the training group. By comparing the improvement scores for the two groups, it was found that those students who received the WCTC training made significantly greater improvement than those in the control group. Drawing on these sets of results, we can conclude that the WCTC program is effective in improving students' problem-solving abilities with fractions.

Statistical analysis comparing the effectiveness of the WCTC program for high, middle, and low performers indicated that middle performers in the training group gained significantly greater than their counterparts in the control group. No differences were observed for high or low performers. In this study, students at all three performance levels of the training group improved at a fairly uniform rate. However, it was the gains made by the middle performers which had the greatest impact when compared to the control group, as demonstrated by the moderate to strong effect size of .652. On the basis of these results, it can be concluded that the WCTC program was most effective in improving middle performers' fraction skills.

4.3 Discussion

Although there was not a significant difference in general mathematics achievement among the classes, classes did have varying degrees of problem-solving skills for fractions. This class difference confounded the analysis of students' posttest performance. Had there been no difference between classes, the class effect could be ignored and a simple ANCOVA of posttest performance would yield a significant result. This class difference in pretest performance can most likely be attributed to the fact that teachers did not all teach the fractions unit at the same time of year. One teacher had completed instruction several months prior to the investigation, a few teachers had just wrapped up a month-long unit, while another class had only received a brief introduction to fractions.

Another factor which most likely contributed to the non-significant comparison of posttest results is the methodological issue that the sample number of classes was not adequate. A larger number of classes would have added more degrees of freedom to the analysis, resulting in a much smaller error term and increased power. Six classes were simply not enough to mediate the effects of different levels of baseline performance.

It is worth noting that training with the WCTC program did accelerate the growth in fractions performance for the treatment group. Although students in the training group scored significantly lower than the control group on the pretest, there was no longer a difference between the groups on the posttest. Receiving the WCTC training allowed the treatment group to “catch up” with the control group that had originally performed better.

The conclusion that the WCTC program was most beneficial for the middle performance group seems to contradict the findings of the pilot study (Wang, 2004). In that study, subjects were divided into only two performance groups, low and high, with only low performers in the training group showing significant improvement. The researcher concluded that training with the WCTC was most effective for low performers. This apparent contradiction might be explained by the fact that the pilot study was conducted with a much smaller sample size (N = 39) and only two performance levels were examined. Perhaps that analysis was not as sensitive to differences which exist across a group of students. The “middle performers” included in the low group may have accounted for a greater amount of the growth attributed to the entire group.

An observation worth noting concerns the behaviors of students who served as subjects in this study. In general, students in both groups seemed highly motivated, especially at the beginning of the investigation. They were eager to participate and seemed willing to give effort to the project. Although an attempt was made to keep the environmental conditions equal for both groups (thereby avoiding a Hawthorne Effect), there were invariably some differences between the two groups.

The main difference is in the amount of direct instruction provided by the investigator. For the treatment group, instruction was provided in how to navigate through the web site and how to answer the quiz questions in a format the computer would accept. Since the organization of the six lessons was nearly identical, students were then able to work through the program independently with a few students receiving assistance as needed.

For the control group, seven educational web sites were used for fractions practice. Each web site had its own organizational structure and set of directions. The investigator therefore had to provide direct instruction as students were introduced to each one. This resulted in a greater amount of attention given to those classes in general compared to the classes who received the WCTC training.

One vital component of the training program lies in the corrective feedback students are given after they complete the quiz and submit it for grading. Students are expected to go back and monitor their performance by rereading the question and the corrective feedback provided. The investigator did not allow students to skip this step. However, it is questionable how much students gained from this experience. In general, students seemed much more concerned with their score than with examining the reasoning behind each correct answer. They just wanted to know, "How many did I get right?" rather than "Why did I miss that one? What is the correct solution procedure?"

Several factors probably contributed to this problem. One lies in the meta-cognitive development of the children who participated. Nine and ten-year-old children do not have well developed thought processes for monitoring their own understanding.

Another factor lies with the program itself. The corrective feedback provided for each question is rather general and follows a common format throughout the program. The same statement is provided for each child regardless of how they answer the question. For example, the corrective feedback for one question states, "You have to make sure the same thing happens between the two fractions. The correct answer is B." Once a student has read the corrective feedback for several questions, they might all begin to sound alike. Students become de-sensitized to the wording so they don't pay close attention to what it says. Also, it may be that the question was difficult to begin with, and now that they have gotten it wrong, they feel discouraged rather than empowered to learn the correct solution. An informal observation made by the investigator was that children spent much less time reading the corrective feedback on the later lessons of the program.

With regards to the instrument used as the pretest and posttest, the items used had been classified by the NAEP into three main categories: Conceptual Understanding, Problem Solving, and Procedural Knowledge. The majority of the questions on this test measured a student's conceptual understanding of fractions. The investigator also classified the questions according to the content knowledge needed to answer each correctly. The groups and question numbers are contained below.

Table 9. Classification of Test Questions by the Investigator

Question Content	Question Numbers on the Test
Naming Fractional Part	# 1, #2, #3, #4, #5
Expressing in Different Terms (Equivalency)	**# 6**, **#7**, #10, **#11**, **#12**
Comparing Fractional Amounts	**#8**, #9
Adding Fractions	**#13**, #14, #15

On the table above, the questions in bold are those on which the treatment group showed significant improvement from pretest to posttest. One can see that the WCTC training seemed to make the most difference on fraction problems where students needed to express a fractional amount in different terms. This makes sense, given the inductive reasoning skills of generalization and recognizing relationships. To find an equivalent fraction, students must first notice the relationship between the two denominators and then make sure the same relationship exists between the two numerators. Finally, they must recognize that the same fractional amount is represented by both fractions, which could be considered a characteristic of the fraction.

It is interesting to note that students did not show significant improvement on questions that simply asked them to name a fractional part. These questions would not involve comparing two amounts to look for similarities and/or differences. This informal analysis seems to support the notion that the WCTC program in most beneficial in improving problem-solving abilities on those questions that involve inductive reasoning.

One aspect of the WCTC examined in this investigation is the readability of the program and its connection with student reading achievement. The only way for students to acquire the inductive reasoning skills taught in the WCTC program is to read and understand the instruction presented in the computer program. Fry's readability formula was used to estimate the level of reading achievement students would need to attain to read and comprehend the information independently (Fry, 1977). Fry's formula provides an estimate of reading difficulty by examining syntactic difficulty and vocabulary difficulty, which are widely acknowledged as two main factors in determining readability. Other factors which influence readability include text features, such as legibility, illustrations, and graphics; familiarity of concepts presented; and author's style.

According to the formula, the WCTC had an average readability at the 6th grade level. Although the organization of the text and inclusion of graphic aids most likely served as a support for students, the unfamiliarity and density of the concepts presented challenges for most readers. After reading each lesson's instruction, students practiced their newly acquired skills by answering questions contained in the WCTC quiz. Quiz performance was used to estimate of the development of students' inductive reasoning abilities when solving fraction problems. In other words, the higher the students scored on the quiz, the more successful they were in leaning the inductive reasoning strategies taught in the lesson.

A moderately strong correlation was observed between students' reading achievement and their scores on the quizzes. It could be argued that kids who are poorer readers were less able to benefit from the instruction provided because they could not independently read and comprehend the material, and therefore did not learn the inductive reasoning strategies as well. Kids who are advanced readers were more successful in reading and comprehending the instruction, which then led to higher performance on the quizzes. There was also a moderately strong, significant correlation between students' quiz performance and their posttest score. In other words, more success on the practice quizzes is associated with a higher degree of skill transfer to the posttest. It seems that a student's reading achievement plays a significant role in how successful he or she is in acquiring the skills taught by the WCTC.

When examining the quiz total score for all students who received the training, it was noted that the average score was 251.13 points out of a possible 600. Dividing this by the six quizzes of 100 points each results in an average of 42 points earned per quiz. In other words, the average student only answered about 4 out of the 10 questions correctly on each lesson. This does not seem like very high level of performance on the quizzes given the fact that the average student got more questions wrong than they got right. However, even with such little success on the practice quizzes, *students still learned enough to make significant gains on the posttest.* This begs the question, if students had been more successful on the WCTC quizzes (say averaging 7 correct answers per quiz), how much better might their skills have transferred to the posttest? Examining the correlation between the two tasks would seem to suggest that increasing a student's success on the quizzes should also lead to improved problem solving skills with fractions. Future research should examine ways to help students experience more success on the tasks presented in the quiz section of the program.

4.4 Recommendations for Program Modification

This section contains suggestions for improvements that could be made to the Web-based Cognitive Training for Children program or in its use with future populations of students.

1. It is the opinion of the investigator that the instruction contained in the WCTC lessons is written at a readability level that is too high for average 4th graders to be successful. In others words, it is simply too hard for many students to read and comprehend independently. If some of the primary users of the WCTC program are students who have trouble learning fractions through regular classroom instruction, this group of low performing students will most likely contain struggling readers. For these students to receive maximum benefit from the program, they need to be able to easily read and understand the material. One possible solution is to revise the text of the instruction so that it is at a lower readability. That way even struggling readers in 4th grade would be able to read it independently. Another possible solution is to simply use the program with older students, such as those in 5th or 6th grade.

2. The corrective feedback at the end of each quiz should be revised so that students are more likely to pay attention to the feedback and think about what it says. This could be done by making the feedback more specific and less repetitive. Also, if students were given a chance to correct a wrong answer using the feedback given, they may pay more attention to the correct solution strategy rather than simply the number correct.

3. In this investigation there were still a few problems with students not getting credit for correct answers that were stated in the wrong format. It was sometimes confusing for students to know how to state their answer in the format expected by the program. The effectiveness of the WCTC may be improved by revising the quiz questions so that the answers are all written in the same format. Another possibility may be to reprogram the grading function of the WCTC so that it will accept all correct answers in several formats.

4.5 Recommendations for Future Research

Although the purpose of this study was to provide scientific-based evidence concerning the instructional effectiveness of the Web-based Cognitive Training for Children as an educational intervention, several questions remain which could serve as the basis for future research.

1. What is the specific connection between students' reading comprehension abilities and their success with the WCTC program?

2. What are the comparative benefits for other sub-groups of students, such as those with an IEP, lower socio-economic students, English language learners, etc.?

3. How do qualitative factors such as motivation and time-on-task contribute to the benefits gained by using the WCTC program?

4. What is the optimal amount of time per training session for students to remain engaged with the program?

5. How do students' performances change as they progress through the lessons? Did their performance get better as they progressed because they were developing inductive reasoning skills and becoming more comfortable with the format and tasks? Did their performance deteriorate over lessons because the questions got harder, they were less attentive to the familiar format, or perhaps they were tired and less motivated?

6. How does the use of inductive reasoning skills as applied to contexts other than fractions change as a result of training with the WCTC program?

Further investigation concerning these questions would verify or refute the reliability of the current study and add to the body of research concerning the transfer of inductive reasoning skills.

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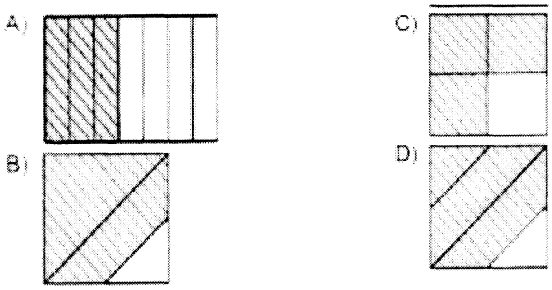
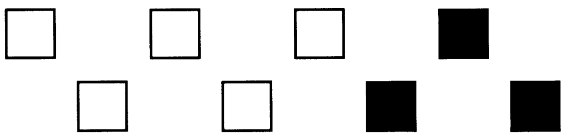
APPENDIX A

FRACTIONS TEST USED FOR PRETEST AND POSTTEST

1. Which shows 3/4 of the picture shaded?

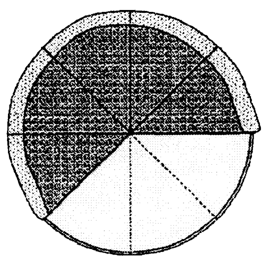


2. How many fourths make a whole? Answer: ______



3. The above set is made up of black and white squares.

What fractional part of the squares is black? ______



4. The figure above shows that part of a pizza has been eaten. What part of the pizza is still there?

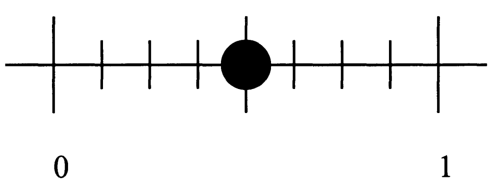
A) 3/8

B) 3/5

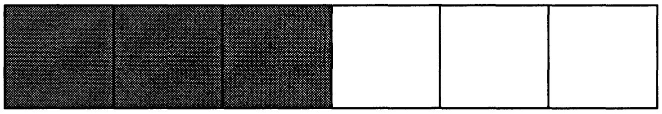
C) 5/8

D) 5/3

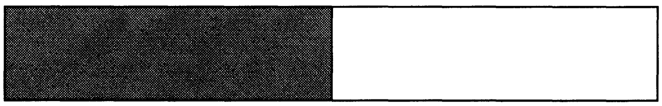
5. On the portion of the number line below, a dot shows where 1/2 is. Use another dot to show where 3/4 is.



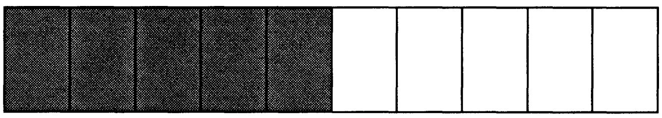
6. The shaded part of each strip below shows a fraction.



A. This fraction strip shows 3/6.



B. What fraction does this fraction strip show? ______



C. What fraction does this fraction strip show? ______

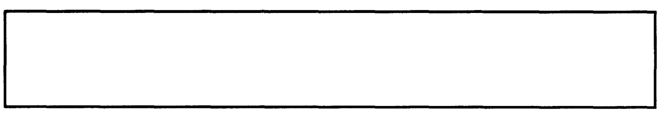
What do the fractions shown in A, B, and C have in common?

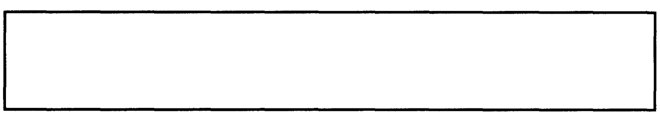
____

____

____

Shade in the fraction strips below to show two different fractions that are equivalent to the ones shown in A, B, and C.





7. Jim has 3/4 of a yard of string that he wishes to divide into pieces, each 1/8 of a yard long. How many pieces will he have?

A) 3

B) 4

C) 6

D) 8

Think carefully about the following question. Write a complete answer. You may use drawings, words, and numbers to explain your answer. Be sure to show all of your work.

8. Jose ate 1/2 of a pizza.
Ella at 1/2 of another pizza.
Jose said that he ate more pizza than Ella, but Ella said they both ate the same amount.

Use words and pictures to show that Jose could be right.

---

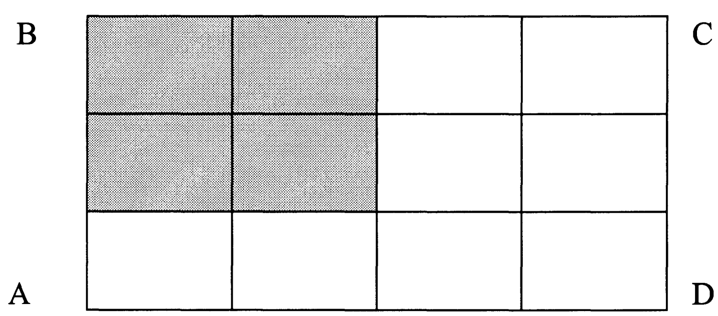
9. Students in Mrs. Johnson's class were asked to tell why 4/5 is greater than 2/3. Whose reason is best?

A) Kelly said, "Because 4 is greater than 2."

B) Keri said, "Because 5 is larger than 3."

C) Kim said, "Because 4/5 is closer than 2/3 to 1."

D) Kevin said, "Because 4 + 5 is more than 2 + 3."



10. In the figure above, what fraction of rectangle ABCD is shaded?

A) 1/6 C) 1/4

B) 1/5 D) 1/3

11. Write an equivalent fraction in lowest terms. 3/9 = _____

---

12. Write this improper fraction as a mixed number. 3/2 = _____

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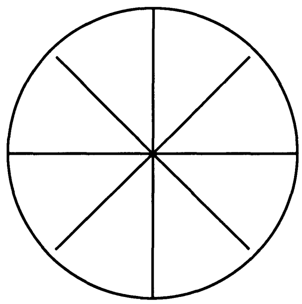
13. Use the picture to help you solve this addition problem.

2/8 + 3/8 = _____



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14. Estimate the answer to 12/13 + 7/8.

A) 1 C) 19

B) 2 D) 21

---

15. What is 1/5+ 3/10? ______

APPENDIX B

EDUCATIONAL WEB SITES USED WITH CONTROL GROUP

1. Fishy Fractions (multiple skills):

   http://www.iknowthat.com/com/L3?Area=FractionGame

2. Soccer (adding and subtracting fractions):

   http://www.funbrain.com/fractop/index.html

3. Adding Fractions (unlike demoninators):

   http://matti.usu.edu/nlvm/nav/frames_asid_106_g_2_t_1.html

4. Fraction Frenzy (equivalent fractions):

   http://www.learningplanet.com/sam/ff/index.asp

5. Math Splat (equivalents, adding, and subtracting fractions):

   http://fen.com/studentactivities/MathSplat/mathsplat.htm

6. Renaming Equivalent Fractions:

   http://matti.usu.edu/nlvm/nav/frames_asid_105_g_2_t_1.html

7. Fresh Baked Fractions (equivalents):

   http://www.funbrain.com/fract/index.html