Computer-Assisted Middle School Mathematics Remediation Intervention: An Outcome Study

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ABSTRACT

Since the No Child Left Behind Act (NCLB) of 2002, educational organizations have undergone increasing pressure to identify and utilize educational interventions that are scientific-research based. The establishment of the efficacy of any educational program depends upon statistically significant scientific demonstrations of "what works, with what children, under what circumstances" (Whitehurst, 2002). The need for this type of examination is great in the area of mathematics. This research presents the results of a 3 X 2 between/within design with non-random assignment of participants to experimental and control conditions. The intent of the research was to investigate the efficacy of a Title I math and after-school program that made extensive use of commercially available mathematical educational computer programs. A convenience sample of 86 fifth (n=34), sixth (n=19), and seventh (n=33) grade students who scored below proficiency on the math portion of the Idaho Standards Achievement Test (ISAT) between spring 2003 and spring 2004. Based on scheduling requirements and limited space in the program, students were nonrandomly assigned to one of two groups: a Treatment group that received the Title I math and after-school program (n=51) or to a no-treatment Comparison group that did not receive that program (n=35). Students were assessed by utilizing the ISAT at four points during the year: spring 2003, fall 2003, winter 2004, and spring 2004. Since the differences in gender, racial background, and grade level were non-significant, all inferential analysis was collapsed over those variables. However, a significant starting difference in the ISAT spring 2003 scores existed between the groups. That measured difference was used as a covariant in the analysis. A 3 (three ISAT testing times) by 2 (Treatment or no-treatment Comparison groups) between/within ANCOVA was calculated. The only significant result was for the main effect of groups (p= .023) with the Treatment group performing significantly better

on the ISAT exams than the no-treatment comparison group. To further investigate the efficacy of the treatment, a Chi-square test was calculated one year after treatment (spring 2004) and found that significantly more Treatment students exceeded or matched their ISAT cutoff scores than those in the no-treatment Comparison students (p = .016).

INTRODUCTION

Ever since the initial, widespread introduction of computers into the modern world, increasing interest has developed in how to best employ computers within the broader educational curriculum. This trend is of course not limited to the United States (e.g. Mamoukaris, Bakatselos, & Economides, 2000; Webster, 2003), it has been brought into sharper focus due to the passage of the NCLB Act of 2002. It is known that the use of various types of multimedia enhances learning (Bagui, 1998) and computers are playing an increasing role in assisting educators in the classrooms. While computers are used in all areas of instruction, this paper will be restricted to the area of mathematical instruction.

Interest in computer-based mathematical education has accelerated over the last 20 years. McCoy (1996), within the context of the underlying philosophy of constructivism, presents a conceptual framework for viewing computer-based mathematical education that splits the content area into two pieces: a programming mode and a computer-assisted instruction mode. The programming mode covers those activities where the individual utilizes logical reasoning to “teach” the computer via the writing of computer programs. Through the use of various programming languages, these students experience how mathematical logic works and receive direct and immediate feedback that enhances their learning of mathematical principles. Computer-assisted instruction is when the computer is used to teach mathematical principles from very simple rote practice to more complex computer simulations that let the students direct the events within that simulation. These computer simulations are also known as “microworlds” (see Papert, 1980 or Hoyles, 1994). This paper will be examining observational results of students involved with a computer-assisted instruction program.

Many different populations are served by computer assisted instruction. While the normal student population is increasingly being exposed to some form of computer-assisted instruction (Becker, 1991), some less obvious examples include the adult population (see Safford-Ramus, 2001 for a review of relevant dissertations), the adult prison population (e.g., Batchelder & Rachel, 2000), and the learning disabled (see meta-analysis by Kroesbergen & Van Luit, 2003). While these unique populations are interesting in their own right, the use of computers in everyday instruction is becoming more and more prevalent. For example in the Miami-Dade public school system for middle school students (Valdez, 2000) specific recommendations were made indicating that they needed to employ only technology and software that has the greatest possible chance for maximum results. The quandary facing Miami-Dade and other school systems is that there exists a shortage of scientific studies that investigate specific technologies and software programs. This problem has been brought into sharp focus due to the passage of the No Child Left Behind Act in 2002 that mandated skill and competency testing in elementary schools with increasing negative consequences for schools whose students failed to make adequate yearly progress. Problems immediately developed due to the lack of existing research and procedural obstacles facing new research. Zvoch & Stevens (2003) found additional problems that occurred when one tried to compare the effects of computer-assisted instruction across schools noting that outcomes based on the assessment of school performance are dependent on the specific choices of data modeling and statistical testing techniques. Such results could be misleading. For example, concluding that a school's poor standardized test scores indicates poor performance when an analysis of other variables, say the amount of improvement or change in those scores, could very well indicate a robust positive effect of a particular computer-assisted instruction program.

These problems and gaps in the research literature led to the Department of Education creation of the "What Works Clearinghouse." This organization's purpose is to serve as a resource for educators by screening the research information being generated today in order to present in one place an easy-to-understand summary of research on identified questions, including mathematical instruction. Up to this date (February, 2005) for the review of mathematical instruction, only 3 studies out of 500 submitted have met the scientific-based standards, all of which were computer-based programs. The "What Works Clearinghouse" accepts both experimental and quasi-experimental studies to review, giving greater weight to the experimental rather than the quasi-experimental. A serious gap in the mathematical education literature exists today due to the very small number of studies, observational or experimental, available today that examines specific interventions available to schools.

Observational or non-equivalent control group studies take advantage of naturally occurring events that lend themselves to accurate data recording. The research presented in this report capitalizes on such an event: the transition from a traditional remedial Title I math program to a computer-assisted Title I remedial math program (combined with voluntary after-school activities) in the Buhl Middle School in Buhl, Idaho over the school year 2003 to 2004. This transition allowed for the comparison of sub-performing students who received the standard classroom instruction and students who received systematic intervention consisting of clearly defined components in the mathematical remedial program.

Buhl Middle School provides remedial education for students who have not demonstrated proficiency as determined by a state achievement test. Students who do not meet proficiency standards on the Idaho State Achievement Test are eligible to receive extra instruction through the Title I math program and a voluntary after-school program. The traditional math remedial program relied on paper-and-pencil instructional materials that were used at the discretion of the teacher in charge of the program. Starting with the 2003/2004 school year, Buhl Middle school changed its program from traditional to one utilizing a systematic instruction program consisting of both computer-aided and paper-and-pencil components. Individual instruction programs were derived from the results of the students' current mathematical knowledge as determined by pre-tests provided by each of the components of the intervention. Subsequently, mastery of topics was determined by post-tests. During this year of transition to the new Title I math and voluntary after-school program, a naturally occurring comparison group of children was generated. These children were eligible for program participation but did not receive it due to scheduling conflicts and limited space. While this subgroup of children did not receive the remedial math intervention, they did spend the same amount of additional time engaged in non-mathematical endeavors both during school and in after-school activities.

The goal, then, of the educational intervention at Buhl Middle School was to provide remedial instruction in mathematics so that those students who had not met proficiency on the Idaho State Achievement Test would be able to meet proficiency. This unique opportunity allowed the gathering of observational data to answer two clear research questions:

1. Did students who were not proficient in mathematics as measured by the Idaho State Achievement Test (spring of 2003), and who participated in the Title I Remedial Mathematics and after-school program for the 2003/2004 school year make greater gains on the ISAT than non-mathematically proficient students who did not participate in the program?
2. Did students who were not proficient in mathematics as measured by the Idaho State Achievement Test (spring of 2003), and who participated in the Title I Remedial Mathematics and after-school program for the 2003/2004 school year meet proficiency at a rate greater than non-mathematically proficient students who did not participate in the program?

METHODOLOGY

Participants

Population Characteristics. The educational intervention under investigation occurred at Buhl Middle School, in Buhl, Idaho. The observational data was collected over a one-time period beginning spring 2003 through spring 2004. Buhl's school district contains an elementary, middle, and high school. Buhl's total population is 9,136 with a median income of about 34 thousand dollars annually (2000 census). This town is about 85% Caucasian, 11.5% Hispanic, and the remaining 3.5% consisting of various minorities (2000 census). The total enrollment in the district is 1,350 students (as of school year 2003). The middle school serves approximately 325 students in grades six, seven, and eight.

Sample Characteristics. A convenience sample of 86 students from the Buhl school district was assessed during the school year of spring 2003 to spring 2004. All of these students scored below their grade-appropriate ISAT cutoff scores in spring 2003.

Approximately equal numbers of male (n=38 or 44.2%) and female (n=48 or 55.8%) students were distributed across three grade levels in the 2003 testing year: 5th grade (n=34 or 39.5%), 6th grade (n=19 or 22.1%), and 7th grade (n=33 or 38.4%). This sample was predominately Caucasian (n=52 or 60.5%) but included a substantial number of students with Hispanic backgrounds (n=26 or 30.2%) with the remaining 9.3% being split among the ethnic categories of Portuguese (n=4), Asian (n=1), Native American (n=2), and Unknown (n=2). There was no significant difference in the distribution of gender, grade or ethnic background across those students who participated in the Title I math and after-school math program and those who did not.

Variables

Dependent variable: Idaho Standards Achievements Test (ISAT) scores. The ISAT is a standardized test that has three content areas: Language Usage, Mathematics and Reading. This test is available in both a paper and a computer version. The mathematics section is comprised of multiple choice format questions covering seven major content areas such as number sense, principles of algebra and geometry, and probability theory. This state-mandated test is produced by the Northwest Evaluation Association, which, while having no specific reliability or validity results for this exact test, does have a series of very similar tests with good reliability and/or validity (Northwest Evaluation Association, 2004).

Independent variable: Title I math and after-school math program participation. Participants were assigned (see procedure) by school administrators to one of two groups. The Treatment group consisted of those that were both enrolled in the Title I remedial mathematics program and who voluntarily attended an after school math help class.

The Comparison group consisted of those that were both enrolled in non-mathematical activities and who voluntarily attended an after school program involved in non-mathematical activities. Both groups continued to receive mathematics instruction in the standard eighth grade classroom.

Title I remedial mathematics program and After-school math program description. This program's core content consisted of three technology-driven, instructional components produced by two educational software companies: the *A+nyWhere Learning System (A+LS*) (American Education Corporation, 2005*)*, the *Accelerated Math* program, and the computer-mediated *Math Facts in a Flash* program (Renaissance Learning, 2001). See below for a detailed description of each component. A teacher was on hand during these sessions to answer questions as needed. Student attendance rates for the voluntary after-school portions for either the mathematical or non-mathematical program was not recorded but reported as consistent and high. Each student participated 4 days a week for about 87.5 minutes each day for a total of about 350 minutes per week in his or her respective activities. Each student in the Treatment group spent 205 minutes working with the *A+LS* component, 100 minutes working with the Accelerated math component, and 45 minutes working with the Math Facts component per week.

A+nyWhere Learning System (A+LS) (American Education Corporation, 2005). The *A+nyWhere Learning System* is a network-installed computer program, with extensive management capabilities. The system provides diagnostic assessments to determine a student's mastery level of instructional objectives, and prescribes lessons to provide instruction in the objectives that have not been mastered.

Each lesson is presented with a consistent methodology. In essence it is a computer-presented lesson based on the principles of mastery learning. Throughout *A+LS*, illustrations are used to provide context and amplification of the concepts presented in print. However, graphics are not used to create a "game-like" experience. It is designed so that it is clear to students that they are in a learning environment. In each lesson, there is a study guide that presents the concept being taught. The study guide is followed by a series of practice exercises in which the student receives immediate feedback regarding the accuracy of his or her answers. Then, there is a mastery test that evaluates the students performance in a specific subject area. The management system provides ongoing feedback to students regarding their overall progress.

At Buhl Middle School, the Title I math teacher manages the laboratory providing the *A+LS* math instruction. This individual is an experienced educator who has been extensively involved with technology integration and instruction at Buhl Middle School. In this implementation, the assessment and prescription functions within *A+LS* were utilized to provide instruction for the students.

The Accelerated Math program (Renaissance Learning, 2004). *Accelerated Math* sets up worksheets for each grade level with about 100 objectives for students to master. It prints a diagnostic test for each objective. If a student masters the objective, that objective is reviewed twice more. If a student does not master the objective, the program prints out practice worksheets for those objectives. Progress and mastery of objectives is recorded in the *Accelerated Math* computer program.

The Math Facts in a Flash program (Renaissance Learning, 2005). *Math Facts* consists of 40 flashcards at each level of instruction that "flash" on the computer screen with four possible answers. Students have two minutes to answer all of these forty problems correctly or they have to redo the problems. In the *Math Facts in a Flash Program*, students complete a timed test at the computer for each new math level. Immediate on-screen feedback provides students with their time and accuracy, and shows any missed problems. Students, then, practice a variety of problems, including those that cause the most difficulty at their levels and any they missed on the previous test. Next, students complete a 40-item timed test for additional practice until all problems are answered correctly within the mastery time goal. Using an assisted-response format, students quickly develop the confidence they need to succeed with the program. As students master their current levels, the program automatically assigns the next math level. The sequence of math levels can be adjusted to fit any curriculum.

Design

A post-hoc convenience sample of student standardized math scores was analyzed in this paper. This design utilized a 3 X 2 between/within analysis of co-variance (ANCOVA) with standardized math test scores (Fall 2003, Winter 2004, and Spring 2004) as the within-subject factor, Treatment group (Treatment or no treatment Comparison) as the between factor, and the student's initial standardized spring 2003 math scores serving as the covariant.

Procedure

Selection of participants. All students who scored below their state-mandated spring 2003 grade-appropriate proficiency math score cutoffs were eligible for the program. The students were enrolled in this program in lieu of an elective subject such as art, or woodworking.

Assignment to treatment group. A nonrandom procedure was used by school administration that determined which math-deficient students participated in the Title I remedial program. This procedure was derived from the real-world limitations of student scheduling conflicts and limited space in the program itself. It is unclear what exactly the conflicts were, or whether it systematically prevented students with certain characteristics from participating in the program. Nevertheless, a group of students to serve as a comparison group was created from the pool of students who did not meet their ISAT grade proficiencies and who did not receive the intervention.

RESULTS

Descriptive statistics

Chi-square tests were conducted to investigate the possible distribution imbalances of Gender, Ethnic background, and Student grade level across Treatment groups. No significant differences were found and these variables were not assessed in the main repeated measure analysis. The Treatment group had significantly higher ISAT scores starting spring 2003 than the no-treatment Comparison group's scores. This initial starting difference was controlled using the student's spring 2003 ISAT scores as a covariant in the analysis.

Inferential statistics

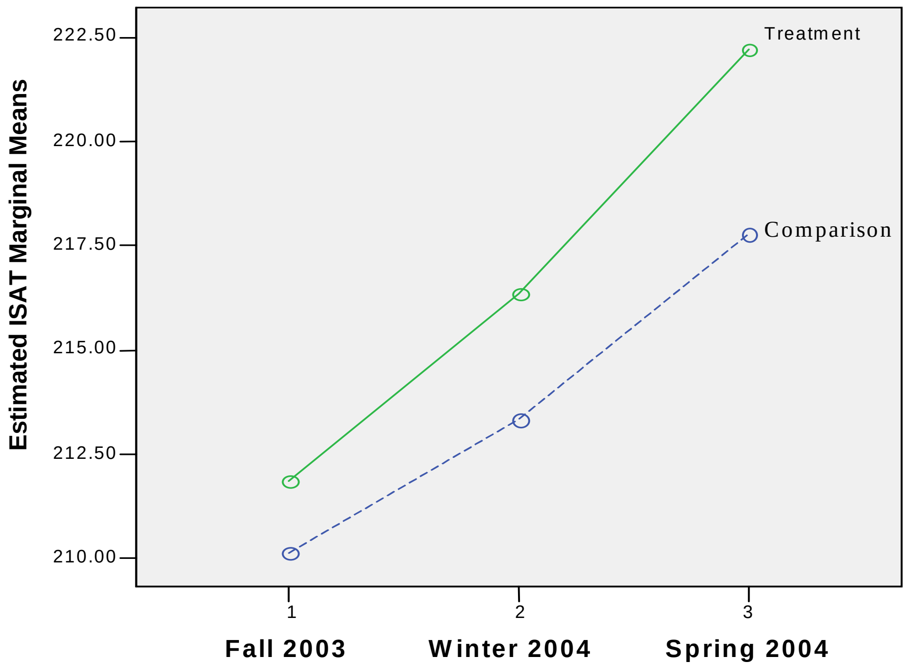
Repeated Measure of Analysis of co-variance (ANCOVA). This first analysis addresses the first research hypothesis asking if math-deficient students who participated in the Title I remedial mathematics program make significantly greater gains on the ISAT than math-deficient students who did not participate in the program. The ISAT scores were analyzed in a 3 x 2 between/within analysis of co-variance with Test (fall 2003, winter 2004, and spring 2004) as the within-subjects factor, Treatment Group (Treatment vs. no treatment Comparison) as the between subjects factor, and the participant's spring 2003 ISAT scores as the covaruabt. Mauchly's test of sphericity was not significant so no degree of freedom correction was needed. The ANCOVA only yielded a significant Group main effect, F (1, 83) = 5.358, p = .023. This main effect has a coefficient of nonlinear correlation (partial Eta-squared) of 0.061 indicating that this variable explained about 6% of the total variance. Please see Table 1 and Graph 1 for the estimated marginal means of the repeated Test variable by Treatment group.

Table 1. **Marginal ISAT means and standard deviations for groups over three testing times.**

Testing Time

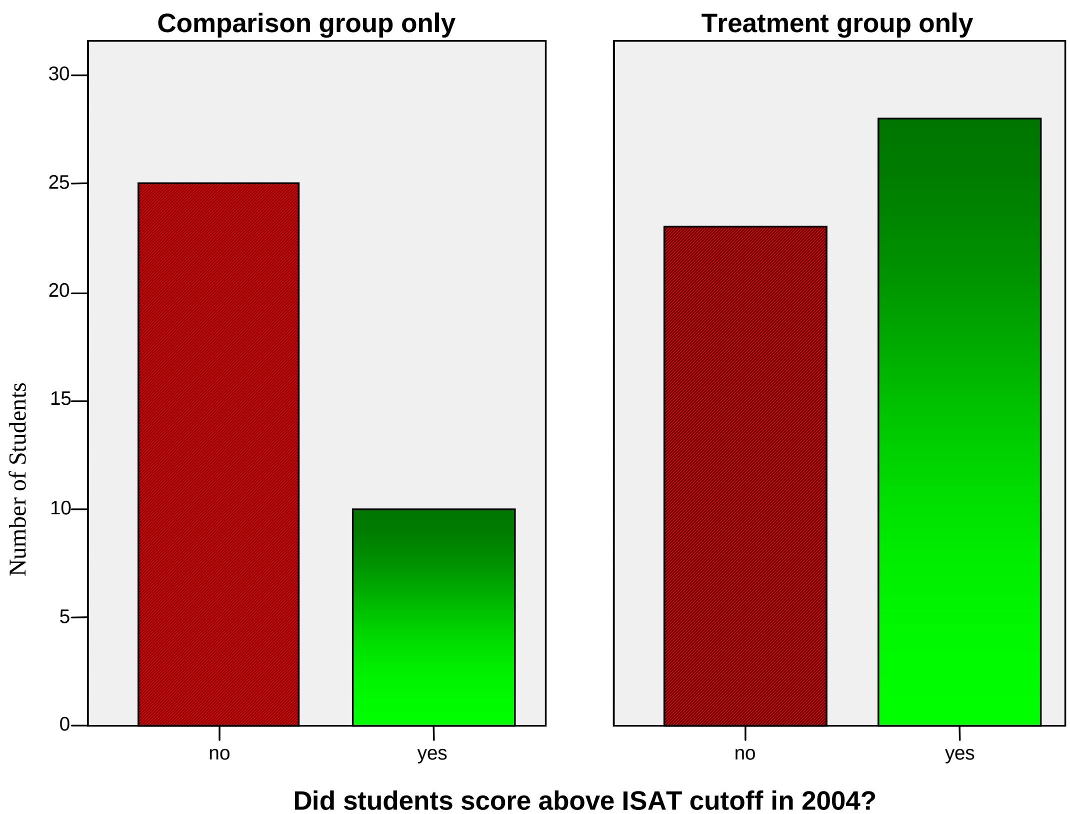
	Fall 2003		**Winter 2004**		**Spring 3004**	
	Mean	SD	Mean	SD	Mean	SD
Comparison	210.129	1.161	213.320	1.290	217.776	1.178
Treatment	211.853	0.956	216.349	1.063	222.212	0.970

Graph 1: ISAT marginal means plotted over three testing dates by treatment group.



Chi-Square. This second analysis addresses the second research hypothesis that investigated whether or not math-deficient students who participated in the Title I remedial mathematics program meet ISAT proficiency at a frequency rate greater than math-deficient students in the comparison group. A Pearson chi-square was calculated comparing the number of students who either exceeded or did not exceed their grade-appropriate math ISAT cutoff scores for spring 2004 by their Treatment group. A significant result was found, X^2 (1, N=86) = 5.835, p = .016 with significantly more Treatment students exceeding or matching their ISAT cutoff scores than the Comparison group. Please see Graph 2.

Graph 2. Number of students meeting or exceeding ISAT cutoffs one year post-treatment by Treatment group.



DISCUSSION

Addressing the needs of students who have not met proficiency has become increasingly important because of the emphasis of the No Child Left Behind Act. Schools and school districts must demonstrate that they are making progress toward all children being proficient. For this reason, the ability to identify educational interventions that raise proficiency rates in schools is essential. This study examined the efficacy of an intervention that systematically utilized three components in raising the proficiency of middle school students in mathematics. The components were the *A+nyWhere Learning System, Accelerated Math,* and *Math Facts in a Flash.* Each was used in a systematic manner designed by the intervention.

The results of this study were encouraging for the employment of a systematic remedial mathematical intervention that relied heavily on computer-aided instruction. While the ANCOVA found that the marginal means were significantly different, $F(1, 83) = 5.358$, $p = .023$, the effect size was small. The partial Eta squared was .061, effectively demonstrating that the effect of the Title I remedial math and after-school program by itself accounted for only 6% of the overall variance. While this effect size is quite small, it does show up despite limitations associated with non-experimental research designs.

Another way to consider the effect size of the outcome is in a way that educators may find more meaningful. This is expressed in the second hypothesis of this paper: Do students in the program reach mathematical proficiency in greater numbers than those who were not in the program? School administrators are concerned with raising the students' proficiency to meet state-mandated requirements. So, a chi-square test is useful to determine if the program was effective in reaching this goal. As the chi-square demonstrates, significantly more students enrolled in the program meet the state requirements than non-program students do. While this is a desirable result, caution must be taken in interpreting the root causes of these results. All that can be claimed is that the program, in its entirety, produced improved performance as compared to mathematically deficient students who did not receive such help. The study does not provide information as to which components were the most important or even if certain components were detrimental to performance.

The limitations associated with this study are common to other non-experimental research. Of the greatest concern is, of course, the lack of random assignment of the students to the groups. Without random assignment, a variety of potential sources of error are possible--from school administrator bias in program assignment to simple sampling error. One obvious problem that very well might have been derived from the lack of random assignment was the significant starting differences in ISAT math scores between the groups as measured in spring 2003. While this difference was corrected statistically, that correction may very well have obscured other results such as significantly diverging curves representing accelerating improvement of the Treatment group over the no-treatment Comparison group.

The applied nature of the study limited the total number of students assessed and limited the type of naturally occurring comparison groups that were available. As noted above, since the comparison group did not receive any part of the intervention or an alternative version of the treatment, the conclusions about the efficacy of the program's individual components are limited. It is true that most efforts at remediation by schools today utilize a variety of commercial products. As a result, the results of this study are useful because there is a greater understanding of a complete remedial intervention. Nevertheless, it would be helpful to understand the contribution of each component to the overall learning process.

The result of this research indicates the need for a more experimental research. Simply, the addition of random assignment to groups in future studies will help control experimental error and address the limitations to interpretation presented by this data set. However, future studies should go beyond that obvious improvement. Additional research should include clearer manipulations of the use of computer-aided instruction in order to separate out its effects from potential effects and interactions with other aspects of a mixed program such as the one used in this study. An example would be one where the students are randomly assigned to differing amounts of exposure to a single computer-assisted program ranging from very high magnitudes to absolutely zero exposure. Such a study would allow experimenters to relate standardized outcomes directly to differing amounts of computer-aided programs. Other studies could investigate potential interactions with differing components by assigning students to programs consisting of one, two or three components. This would allow for the study of potential interactions and allow for the investigation of exactly what combination of components works with various demographically sorted groups of students.

This study does provide evidence for the efficacy of this mixed-component mathematical remedial program. The *A+nyWhere Learning System, Accelerated Math,* and *Math Facts in a Flash* all contained a diagnostic component that prescribed the activities for the student based on the student's needs. Each component was used for the amount of time determined by the intervention's design. While there are distinct limitations upon the interpretation of the results, the results do provide encouragement and the basis for further research into the use of highly structured and prescriptive remedial interventions.

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