Use of an Instructional Management System to Enhance Math Instruction of Gifted and Talented Students

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The effect of a self-directed mathematics program on the math achievement of students who are gifted and talented (GT) was evaluated. An instructional management system, Accelerated Math (Advantage Learning Systems, 1998a), was used to assign instruction, monitor student progress, and provide teachers with the information they needed to differentiate math instruction for GT learners. Students whose teachers used the instructional management system significantly outperformed the GT students who participated only in the standard curriculum. Both quantitative and qualitative differences in the performance of GT and non-GT students were identified and within-group variability among GT students is considered.

Introduction

Gifted and talented students are educated in diverse environments. Most are educated in general education classes, others in a variety of pull-out or set-aside programs. Across those diverse environments teachers of students who are gifted and talented face similar types of challenges. One of the major challenges is how to pace and differentiate the curriculum and instruction to address the individual needs and abilities of those students, especially in contexts that include large numbers of students who are not gifted and talented (Renzulli & Reis, 1998; Stanley & Benbow, 1983; Tomlinson, 2001).

There are two interconnected themes in the literature on educating gifted and talented students: (a) access to challenging opportunities to learn and (b) provisions in classrooms to accommodate their unique needs. Provision of differentiated instruction and challeng-

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ing academic activities requires that teachers have access to and use massive amounts of information on student performance and progress. They must know much about performance and progress in order to implement evidence-based components of effective instruction. We know what works in instructing students who are gifted and talented (there is a well-confirmed knowledge base on effective instruction); yet, it is a challenge to implement all components of effective instruction.

There are many summaries on components of effective instruction (Algozzine & Ysseldyke, 1992; Walberg, 1984; Ysseldyke & Christenson, 1987; Ysseldyke & Elliott, 1999), and a general conclusion that the components of effective instruction are similar for gifted and nongifted students. Instructional outcomes are enhanced when instruction is matched appropriately to the skill development of individual learners; there is a positive and efficiently managed classroom environment; motivational strategies are appropriate for the individual student; and students get plenty of relevant practice, informed feedback, and academically engaged time. It is also clear that instructional outcomes are enhanced when teachers know the skills students do and do not have, personalize goal setting, and get feedback on individual student performance and progress toward specific standards or classroom objectives

Mathematics is an instructional area where opportunity to learn has a direct effect on achievement. Math skills are not developed in isolation, but are developed through undertaking challenging problems and comprehending, at times, complex ideas. This does not happen by accident; usually, it must be planned and directed and is a direct function of teaching. This is especially true for gifted students (Lappan, 1999). Provision of increased opportunity to learn advanced content is one way to accelerate the learning of students who are gifted.

It has been reported that many students classified as gifted and talented have not been challenged to work to their full potential (U.S. Department of Education, 1993a) and that top American students have also fallen consistently behind other top students from other industrialized countries (Callahan, 1997; U.S. Department of Education, 1993a). This has been rather significant in the area of mathematics (Beaton et al., 1996; Reese, Miller, Mazzeo, & Dossey, 1997). There have been many speculations about the various reasons for this discrepancy (Callahan; O'Connell Ross; U.S. Department of Education, 1993b).

Many gifted and talented students are generally not receiving instruction tailored to their unique needs (Archambault et al., 1993; Westberg, Archambault, Dobyns, & Salvin, 1993). The U.S.

Department of Education (1993a) also reported that many teachers give the same assignments to gifted and average students in the classroom. This does not reinforce high expectations or work to challenge precocious youth. The teachers we work with say they have difficulty matching instruction to the skill levels in today's diverse classrooms. They say they are especially challenged by students at the margins: gifted and talented students at one end and those with significant skill deficits at the other.

Many options have been proffered as to how best to modify the curriculum to meet the needs of gifted students (Berger, 1991; Roets, 1993; Sheffield, 1994; Waxman, Robinson, & Mukhopadhyay, 1996). Many of these interventions involve accelerating or enriching the content of instruction. This suggests the need to adapt the learning environment to provide advanced topics and activities to keep pace with these students' learning.

Davis and Rimm (1994) described the challenges teachers face in differentiating the curriculum and individualizing instruction for students. In an era of significant accountability and a push to get all students to meet higher standards, we see increased focus on students who are low performing and a commensurate failure to differentiate and focus on instruction for gifted and talented students. In an era in which federal law calls for the implementation of evidence-based instruction, teachers struggle to find the curricula and interventions necessary to enable them to provide all students with instruction that works.

An effective curriculum for gifted students needs to modify instruction to a pace and content level that is engaging to the student (Berger, 1991). This means that, in some manner, gifted students should be provided advanced learning activities. This is especially important in the domain of mathematics, where essential content and skills must be learned through experience. However, much of one's experience with math concepts comes from school-related instruction.

Flexible pacing is a key concept in structuring mathematics programs for gifted students (Miller, 1990). One method to achieve this is to use continuous progress reports where the student receives appropriate daily instruction that enables him or her to move ahead at a pace that is comfortable. This allows the opportunity to move at a pace commensurate with ability level while, at the same time, providing opportunity for teacher feedback, direction, and structure. It is difficult for teachers to manage continuous monitoring and performance review for children who are working ahead at their own pace. This can be a significant logistical nightmare for many teachers because, oftentimes, there aren't enough hours in the day to accomplish individualized assessment and monitor pace, provide students with appropriate structured feedback, and give them practice in learning advanced concepts.

Accelerated Math (AM; Renaissance Learning, 1998a) is a curriculum-based instructional management system for mathematics. It is based on a number of what are called "Renaissance Learning Principles." These principles include the following: assessment of student skill level and provision of instruction matched to skill level, personalized goal setting, provision of significant amounts of practice time, and provision of direct and immediate feedback to students and teachers on the students' performance.

Previously, in a large quasi-experiment, we examined the extent to which the use of Accelerated Math (Renaissance Learning, 1998a) enhanced achievement outcomes for students in grades 3–6 (Ysseldyke & Tardrew, 2002). We did so based on the fact that AM incorporates evidence-based principles of effective instruction and earlier was found to be effective in enhancing instructional outcomes for diverse students in elementary school settings. For example, Spicuzza et al. (2001) and Ysseldyke, Spicuzza, Kosciolek, Teelucksingh, et al. (2003) implemented AM as an enhancement to the Everyday Math curriculum in a large urban school district. They found that use of AM led to improved math achievement and increased the frequency with which components of effective instruction known to enhance achievement were present in students' instruction.

Ysseldyke, Spicuzza, Kosciolek, and Boys (2003) found that implementation of AM led to students' spending more time on classroom activities that researchers have identified as contributing to positive academic outcomes. Students who participated in the program demonstrated significantly higher gains in math achievement than students who did not. Accelerated Math (Advantage Learning Systems, 1998a) gives students instant feedback on their instructional performance, gives teachers printouts showing the progress of all students in the class, and provides information about what to teach and how to match instruction to the level of skill development of the learner.

Purpose

This study examined the extent to which teacher use of a curriculum-based instructional management system as an instructional enhancement would result in differential effects in mathematics achievement for gifted and talented students in comparison to gifted and talented students whose teachers did not use the system. We also examined what happens to gifted and talented students when such an instructional management system is put in place. In addition, we looked at the differences in gains between the GT students and non-GT students receiving the AM intervention, non-GT students receiving AM, and non-GT students not receiving AM.

Given our earlier findings that this intervention was very effective for students in general, we wanted to examine its impact on the performance of students who are gifted and talented. In addition, we examined qualitative aspects of achievement, including variability among students who are gifted and between them and other students in practice items completed, percent correct on practice items, tests completed, percent correct on tests, and objectives mastered.

Method

We conducted both qualitative and quantitative analyses. For the quantitative analysis, we used a four-group pretest, posttest control-group design. This design consisted of two sets of two grouping variables each. These groupings were students receiving AM instruction (experimental and control groups) and students diagnosed as GT or non-GT in the states in which they resided. This allowed us to evaluate the hypothesis that gifted and talented students given the self-paced mathematics intervention would show greater gains in mathematics achievement than similar GT students who received no intervention other than the regular math instruction they were receiving. This also allowed the opportunity to evaluate differences in gains between the students identified as GT and those who were non-GT. This design allowed for a control group comparison of outcome results of the gains in achievement levels for students involved in AM intervention. The intervention spanned a 4-month period of time between pretest and posttest.

An analysis of covariance method (ANCOVA) was used to evaluate differences at posttest and determine whether or not gains were significant while controlling for status on pretest results. It was not suspected that the two groups of GT students would differ on the pretest; they were not systematically assigned to experimental and control groups. This was an ideal situation for conducting ANCOVA (Howell, 2002). When used in this manner, ANCOVA removes any bias in the dependent variable means that might be caused by chance group differences on the covariate, which, in this case, was the pretest mathematics achievement status.

We also compared the results for GT students in the AM classroom ($n = 48$) to the non-GT students who received AM ($n = 743$). This type of analysis enabled us to understand whether or not the intervention had differential effects for GT students when compared to regular education students. We also compared the performance of GT students who participated in AM ($n = 48$) with non-GT students who participated in AM ($n = 743$) on a number of qualitative indices.

Participants

The students were part of a larger study in which AM was implemented with an experimental group of 1,130 students and a control group of 1,072 students in classrooms in the same schools as the experimental students. Four groups of students were evaluated in this study. Two of the groups were made up of students who were classified as gifted and talented in the states in which they were enrolled (AL, CA, IA, ID, IL, IN, MI, MN, MO, OH, TN, TX, VA, WA, WI). Demographic data on the GT student participants are shown in Table 1. The last two groups comprised regular education students who received the AM intervention and those who did not (see Table 2).

Forty-eight GT students were enrolled in classrooms that used the AM program in addition to their regular math program. An additional 52 GT students were enrolled in the same schools, but in classrooms that did not use AM. Ten of the schools had GT students in both the experimental and control classrooms.

Measurements

STAR Math (Renaissance Learning, 1998b) is a computer adaptive test of mathematics skills designed to be used with grades 3–12. It measures mathematics skills in relation to numeric concepts, computation, and math applications. It was utilized as the pretest and posttest measure of student mathematics achievement. The test uses an adaptive branching algorithm to adjust the test to the level of the student's ability. On average, it takes approximately 15 minutes for a student to respond to the 24 items. Performance on STAR Math is correlated moderately high, as would be expected, with performance on the mathematics subtests of major achievement

Table 1

Demographic Information for Gifted and Talented Students in Grades 3–6 Who Participated in the Accelerated Math Program

		Grade				
Race	Gender	3	4	5	6	Total
Asian	Males	1	0	0	0	1
	Females	0	0	0	0	0
African American	Males	0	1	0	0	1
	Females	0	0	1	0	1
Hispanic	Males	1	0	0	0	1
	Females	0	0	0	0	0
White	Males	4	5	5	3	17
	Females	7	14	6	0	27
Unspecified	Males	0	0	0	0	0
	Females	0	0	0	0	0
Totals		13	20	12	3	48

tests like the California Achievement Test, Iowa Tests of Basic Skills, and the Metropolitan Achievement Test (Renaissance Learning).

Accelerated Math (AM; Renaissance Learning, 1998a) is a curriculum-based instructional management system that was used as the main intervention. AM was implemented for approximately 4 months. It is a computer-based instructional system that allows students the opportunity to work at a self-selected pace. It is flexible enough to allow students the opportunity to develop more advanced mathematics skills if their pace and understanding move ahead of others. AM helps teachers assign instruction that is matched to the skill development of the learner and monitors student progress toward mastery of math objectives. It also provides immediate feedback to both the teacher and student on mathematics performance. The program has been found to enhance mastery of math skills in the regular educational environment (Spicuzza, Ysseldyke, Lemkuil,

Table 2

Demographic Information for Nongifted and Talented Students in Grades 3–6 Who Participated in the Accelerated Math Program

		Grade				
Race	Gender	3	4	5	6	Total
Asian	Males	0	3	1	0	4
	Females	1	0	0	0	1
African American	Males	7	10	8	2	27
	Females	5	4	6	1	16
Hispanic	Males	13	4	0	3	20
	Females	5	6	0	7	18
Native American	Males	1	10	0	0	11
	Females	1	7	0	1	9
White	Males	54	104	108	36	302
	Females	60	98	88	41	287
	Unspecified	0	0	0	1	1
Unspecified	Males	11	1	2	0	14
	Females	10	0	0	0	10
	Unspecified	0	0	23	0	23
Totals		168	247	236	92	743

et al., 2001; Ysseldyke & Tardrew, 2002; Ysseldyke, Spicuzza, et al., 2003).

AM has 12 standard or major libraries of math objectives, ranging from Grade 3 through Calculus. Each of these libraries consists of math objectives covering a full school year's worth of topics. Each student works in a library that is matched to his or her individual skill level. For example, a fifth-grade student who has average mathematics skills and understanding might start in the fifth-grade library. This library consists of more than 170 objectives, which can be reordered to match the teacher's planned curriculum. The teacher can decide to provide practice on all objectives in a library or only those for which they intend to provide direct instruction. Objectives within a library can be assigned to all students at the same time or to groups or individual students according to their pace of learning.

The program creates individualized practice assignments for students using an Algorithm Problem Generator. This allows each student to work on assignments at his or her own instructional level with a continuous supply of new problems and assignments. At their seat, students work on math practice problems printed by the program; they then scan their completed answers into the computer. Students are able to then test themselves on the objectives within the library in which they are working to assess mastery of the objective. When a student passes a test on an objective, he or she moves on to the next objective.

AM automatically scores these practice assignments and the students' test results. It keeps records of each student and class performance. It also provides information to teachers on individual and classwide progress. Diagnostic reports are also generated to help instructors pinpoint student difficulties and develop interventions to address them.

AM provides important information on other variables of interest. These variables are the number of practice items attempted and percent correct, the number of test items attempted and percent correct, and the number of objectives mastered in each major library.

Results

We conducted an ANCOVA to examine differences in gains in math achievement between GT students who participated in AM intervention and GT students who were provided no intervention. We used pretest STAR normal curve equivalent (NCE) as the covariate and posttest STAR NCE as the dependent variable. The results can be seen in Figure 1 for the pretest and posttest results for the GT students, Figure 2 for the pretest and posttest results for the non-GT students, and in Tables 3 and 4 for the overall results.

Results suggested that the pretest scores were not significantly different between the GT students. There was a significant difference in gain as a function of treatment ($F = 6.77$, $p < .01$) in favor of the group provided the AM intervention. The mean NCE gain for the experimental group was 11.9 NCE, and the mean NCE gain for the control group was 4.8, a difference of 7.1 NCE. The effect size

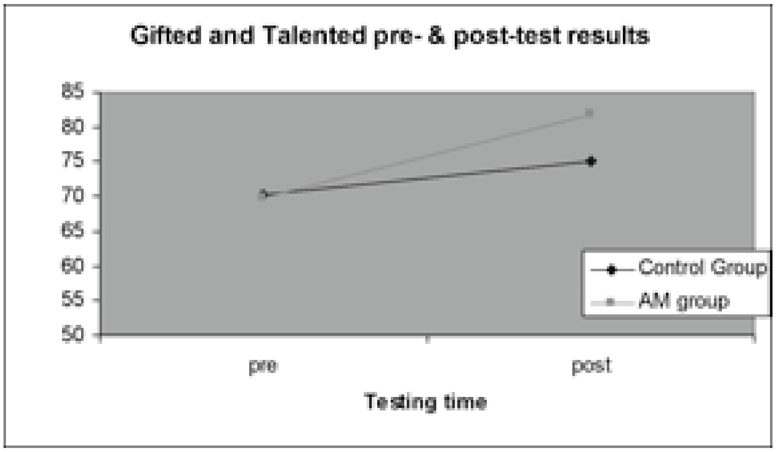

Figure 1. Illustration of pre- and posttest NCE scores for gifted and talented students who did and did not participate in the Accelerated Math program.

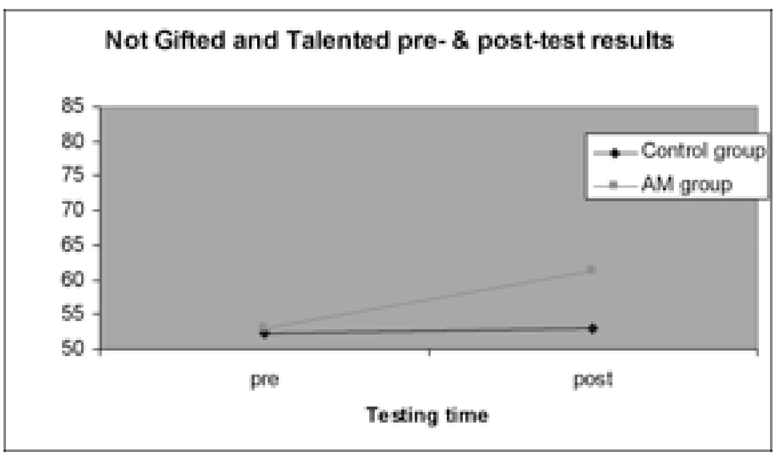

Figure 2. Illustration of pre- and posttest NCE scores for nongifted and talented students who did and did not participate in the Accelerated Math program.

was estimated to be about 0.45, which indicated a large practical effect for the AM intervention (see Table 4).

We also examined differences between 743 non-GT students who were in the experimental group for the Ysseldyke & Tardrew (2002) study and the 48 GT students in the experimental group. Results of

Table 3

Pre- and Posttest Results for Gifted and Nongifted Accelerated Math and Control Students

		Gifted		All other students	
		Control	Accelerated Math	Control	Accelerated Math
N		52	48	736	743
Avg. days btwn pre- and posttest		137	139	139	147
Pre NCE	Mean	70.2	69.9	52.4	53.1
	SD	15.5	18.8	18.1	17.5
Post NCE	Mean	75	81.8	53.1	61.3
	SD	13.3	17.7	19.2	21.4
NCE gain	Mean	4.8**	11.9*	0.6	8.1*
	SD	15.7	16.2	15.3	16.9
AM gain vs. control gain	*F*	6.765		90.987	
	p	0.01		< 0.001	

*Gain significant at the p < .001 level.
**Gain significant at the p < .05 level.

Table 4

Effect Size (Cohen's *d*) for Gifted and Nongifted Accelerated Math and Control Students

	ES
Gifted AM versus gifted control[1]	0.45
Nongifted AM versus nongifted control[1]	0.47
Gifted AM vs. nongifted AM[2]	0.23
Gifted control versus nongifted control[2]	0.27

Note. [1]Effect of Accelerated Math. [2]Effect of being gifted or nongifted.

Table 5

Qualitative Comparison for Gifted and Talented and Nongifted and Talented Students Participating in Accelerated Math

			Mean	*SD*	*F*	Sig.
Practice Items	Attempted	GT	640	557.1	4.29	0.04
		Non-GT	532.3	335		
	% Correct	GT	88.4	6.8	31.249	< .001
		Non-GT	81.1	9		
Test items	Attempted	GT	411.8	396.4	10.639	0.001
		Non-GT	302	212.8		
	% Correct	GT	91.9	4.9	15.742	< .001
		Non-GT	87.9	6.9		
Objectives mastered		GT	85	73.2	12.899	< .001
		Non-GT	63	38.8		

the ANCOVA ($F = 9.718$, $p = .002$) indicated significantly greater outcomes for GT students when compared to non-GT students participating in the experimental condition. We also analyzed these two groups on "process variables" (such as percentage of items correct on math practice exercises). In Table 5, we show the means, standard deviations, and *F* tests associated with the different variables of interest for and between the two groups.

There were significant differences between groups in percent correct on practice exercises ($p < .01$), number of tests attempted ($p < .001$), percent correct on tests ($p < .001$), and objectives mastered ($p < .001$). There were no significant differences between groups on practice items attempted.

These results suggested that GT students did not attempt any more practice items when compared to non-GT students. However, GT students were able to get a greater percentage of their practice items correct. These students also attempted more test items and were able to get a higher percentage correct when compared with their non-GT peers. It is not surprising that the GT students were also able to master a significantly larger number of objectives since mastery of objectives is related to the number of tests completed and mastered.

The final analysis completed was one of variability among gifted and talented students in each of the intervention variables. Figures 3, 4, and 5 are histograms showing the performance of gifted and tal-

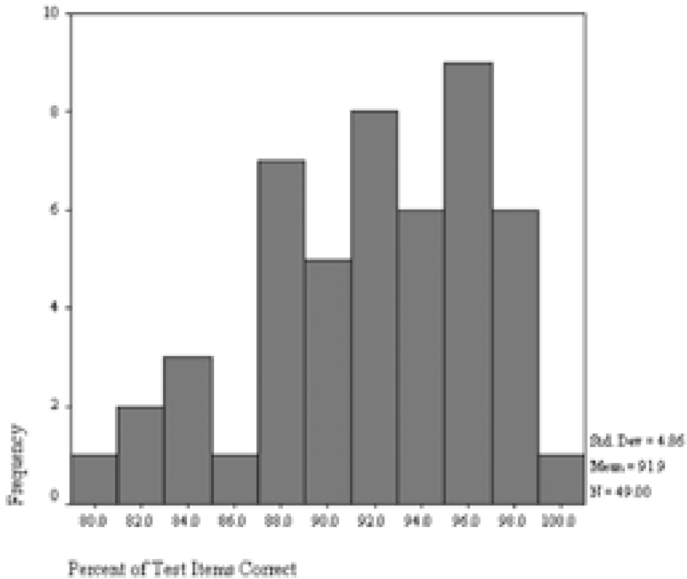

Figure 3. Percentage of test items correct for gifted and talented students.

ented students. The histograms enable readers to see that there is significant variability among the gifted and talented students in the intervention factors. For example, gifted and talented students attempted an average of 640 practice items, with most attempting between 200 and 800 items. Yet, there were GT students who attempted as many as 2,400 items. With the exception of four, all GT students got more than 75% of the practice items correct. All GT students achieved more than 80% correct on test items.

Discussion

Given recent indications that GT students are not being challenged or provided individualized instruction commensurate with their abilities, this study sought to evaluate the usefulness of an instructional management system on mathematics achievement of GT students. AM is a curriculum-based instructional management system that makes work easier for teachers. It is used to track student performance in the curriculum, assign work, and let teachers know when students need assistance. It facilitates differentiated instruction in mathematics, enabling individual students to make progress

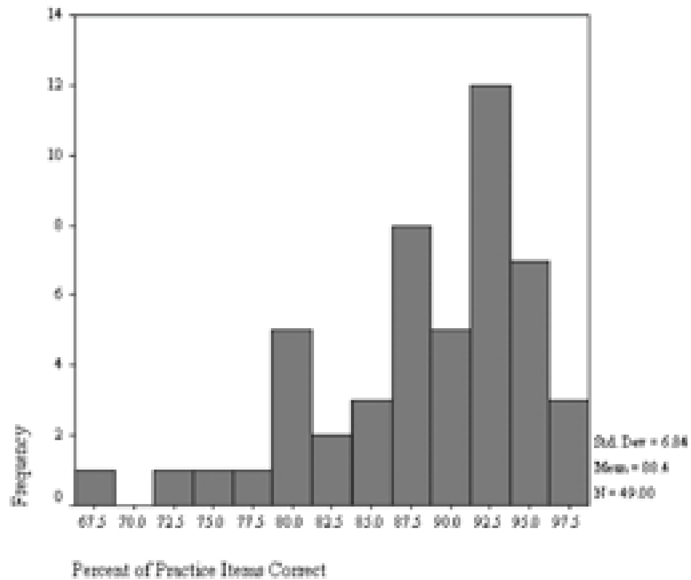

Figure 4. *Percentage of practice items correct.*

at their own speed. We studied its use and effectiveness because it incorporates evidence-based principles of effective instruction.

The results of this study indicated that GT students do profit from access to the AM intervention. This suggests that a structured and engaging intervention that provides an option for students to proceed at their own pace and that also manages instruction for teachers has a great practical advantage to the regular curriculum provided to gifted and talented students. The fact that we were able to accelerate performance and achievement so radically validates many of the findings in the literature indicating that GT students are not being provided effective interventions that allow them to capitalize on their abilities.

These results might suggest that simply giving a student any intervention will result in greater growth. This may be true to some extent, but the fact is that the control group in our study was identified as gifted and talented and designated to be provided appropriate instruction. What our research indicated is that the extent to which students are merely provided extra time and opportunity for learning may not matter as much as the type and structure of the practice provided matched with individual pacing and feedback.

For example, gifted and talented students in the same schools had very different outcomes as a function of taking the intervention or

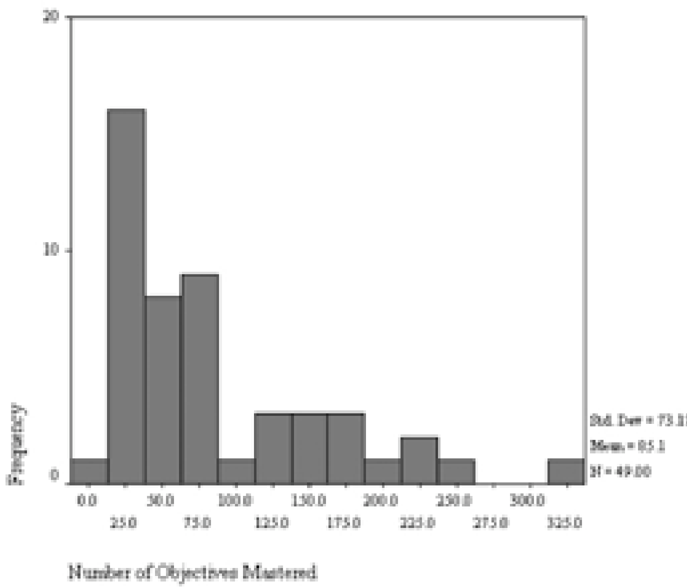

Figure 5. Number of objects mastered.

not. The students in AM had significantly greater outcomes than similar gifted and talented students within the same school. This suggests that the students, when left to their own devises or the regular curriculum enhancements, do not advance with a great deal of mathematics gains. This is also indicated in the large effect size computed between the two groups of gifted and talented students.

There is also prior evidence suggesting that AM enhances the mathematics achievement outcomes in the average general education classroom. These present findings further indicated its effectiveness with GT students in a mixed-classroom environment. Differentiated and enriched instruction of students who are gifted and talented is often difficult to achieve. It is also reasonable to assume that an instructional management system, such as AM, would help teachers achieve better results for GT students while reducing the amount of time of assessment and instruction needed by the teacher.

The results indicated that GT students profit from being able to engage in an individualized mathematics intervention. Use of AM resulted in significant increases in performance for students who are gifted and talented. There were significant differences in math achievement between GT students whose teachers used the program and GT students whose teachers did not use the program. It is suggested that this type of individualized pacing and feedback from the instructional management system provides a structured method of providing advanced concepts, skills, and practice to GT students.

This intervention provided the GT students an opportunity to explore and use concepts beyond those being taught in the classroom. This type of availability of advanced concepts and continued practice with immediate feedback is a vital component of GT education. This study provides definite evidence that, when provided individualized and self-paced instruction in mathematics through an instructional management system, GT students were able to increase their mathematics achievement significantly. This suggests that these students were better able to take advantage of their higher abilities to work at a level in line with their individual needs, rather than being constrained by environmental factors that are almost always out of their control.

A detailed examination of the data considering implementation factors, such as practice items attempted and quality of performance on practice items, test items attempted and responded to correctly, and objectives mastered, showed that GT students significantly outperformed non-GT students. And, importantly, there was considerable variability in the performance of GT students who participated in the intervention. Use of an instructional management system like Accelerated Math enables teachers to differentiate instruction in math and better meet the unique needs of gifted and talented learners.

These results also suggest that GT students were able to move at a more rapid pace than non-GT peers within a mixed classroom environment. It could be suspected that GT students would score significantly higher on percent correct of practice and test items since these students were classified as GT within their respective states. However, the interesting thing is that the GT students attempted a significantly higher number of tests and mastered more mathematics objectives. This provides evidence of the student's abilities to ascertain and complete more topics in a similar amount of time as non-GT peers. However, without an individualized instructional system, these students may not have had the opportunity to learn these more advanced concepts in lieu of the intervention.

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