ACCELERATED MATHEMATICS IN GRADES 4–6

SUMMARY OF A QUASI-EXPERIMENTAL STUDY IN NORTH RHINE-WESTPHALIA, GERMANY

PROF. DR. RAINER H. LEHMANN

DR. SUSAN SEEBER

ACCELERATED MATHEMATICS IN GRADES 4–6

Prof. Dr. Rainer H. Lehmann
Dr. Susan Seeber

Copyright ©2005 by Renaissance Learning, Inc.

All rights reserved. No portion of this book may be reproduced, by any process or technique, without the express written consent of the publisher.

Accelerated Math, Accelerated Reader, "Better Data, Better Learning," Renaissance, Renaissance Learning, Renaissance Place, STAR Early Literacy, STAR Math, STAR Reading, and StandardsMaster are trademarks of Renaissance Learning, Inc., registered or pending registration in the United States and other countries.

RENAISSANCE LEARNING
PO Box 8036
Wisconsin Rapids, WI 54495-8036
(866) 846-7323
www.renlearn.com

ACCELERATED MATHEMATICS IN GRADES 4–6

Summary of a Quasi-Experimental Study in North Rhine-Westphalia, Germany

CONTENTS

OVERVIEW

In 2004, a developmental German adaptation of the Accelerated Math program was implemented in 22 fourth-, fifth-, and sixth-grade classrooms in 14 schools in the German state of North Rhine-Westphalia (NRW). The classrooms using Accelerated Math were matched with an approximately equal number of same-school, same-grade control classrooms that used their regular instructional methods. A total of more than 1,200 students participated in the study.

The following describes key results from a report authored by Dr. Rainer H. Lehmann and Dr. Susan Seeber of Humboldt University in Berlin titled *Accelerated Mathematics in Grades 4–6: Evaluation of an Experimental Innovation in North Rhine-Westphalia.* The report describes a quasi-experimental study of the effectiveness of Accelerated Math, a curriculum-based instructional management system developed by U.S.-based Renaissance Learning, Inc.

This evaluation demonstrated the effectiveness of the Accelerated Math approach in terms of growth in mathematics achievement over a period of just four months. Specific findings include:

- Achievement gains were unexpectedly high both in Accelerated Math and control classrooms. Fifth-grade students using Accelerated Math achieved an increase from pre- to post-test that was approximately twice that of the control group. In grades four and six, the Accelerated Math students and control students experienced similar levels of growth.

- Classrooms in which the Accelerated Math program was used very extensively achieved the largest gains. Classrooms in which Accelerated Math was not fully implemented achieved about the same gains as control classes.

- Some teachers who used Accelerated Math also taught same-school, same-grade control classes using traditional methods. In these cases, the influence of the teacher can be controlled while examining results. Of those classes, most (six out of nine) Accelerated Math classes outperformed their control counterparts taught by the same teachers.

- When surveyed about their experiences with Accelerated Math, overall, teachers accepted the program as an interesting new approach to teaching mathematics. From the teachers' point of view, Accelerated Math is not only a promising approach to increased instructional differentiation and improved diagnostic reliability, but it also promotes the creation of learning environments that support self-regulated, highly individualized learning.

More detailed information on the study design and findings can be found in the following sections of this summary. Alternatively, the full report in German can be obtained at: http://www2.hu-berlin.de/empir_bf/lehmann.html. In addition to summarizing the full report, this document contains a description of the Accelerated Math system as well as a brief description of the German school system.

About Accelerated Math

Accelerated Math is a curriculum-based instructional management system that was developed by U.S.-based Renaissance Learning, Inc. It is intended to accelerate the learning of mathematics when used in conjunction with the existing instructional practices and textbook already in place in the classroom. It is designed to:

- Keep track of individual students' daily activities (the program prints and scores personalized practice assignments and tests for each student);
- Provide immediate feedback to students and teachers through information generated from individual or class diagnostic reports;
- Alert teachers when students are having difficulty with certain math objectives; and
- Monitor student achievement.

Accelerated Math is intended to help both teachers and students ensure that students are working at an appropriate level, mastering new objectives, and reviewing skills they have already mastered. With the information provided by Accelerated Math, teachers have the opportunity to make informed instructional decisions and tailor math interventions to meet the needs of individual students.

Several independent studies conducted in the United States have been able to demonstrate positive effects of Accelerated Math on student performance. This study is the first to evaluate a German version of Accelerated Math. The piloted system included student content in German and teacher materials in English.

Study Design

In 2003, the educational ministry of NRW expressed interest in piloting a German version of Accelerated Math. The study was designed to both inform future development of the German version of Accelerated Math, and to provide information to the educational ministry of NRW in making decisions about future use of the system. Prof. Dr. Rainer H. Lehmann of Humboldt University in Berlin was selected to conduct the study.

The study was designed to answer the following major research questions:

- To what extent are there evidence-supported differences in math performance gains for students in grades four, five, and six who participate in Accelerated Math versus a control group of students in their same grade?

- What is the relationship between student achievement gain and the intensity of Accelerated Math implementation?

- How do teachers evaluate the realization of didactic intention, the curricular differentiation and the implementation of Accelerated Math in the classroom?

To answer these questions, the researchers selected a battery of standardized assessment tools and evaluation instruments to measure achievement gains and comprehensively evaluate the didactic and methodological aspects of this approach. In addition to the two achievement tests designed to measure the mathematical competency of the students at the beginning and end of the evaluation, a nonverbal intelligence test and questionnaires for students and teachers measuring their attitudes about and motivation for mathematic instruction were used. In addition, a teacher questionnaire was employed to determine the teachers' general attitude toward their work and profession, self concept in connection with selected aspects of mathematical instruction, and the teachers' evaluation of the use of Accelerated Math. Each test instrument is described briefly below.

Mathematics Test. Students in grades four and five were assessed using the *Hamburger Schulleistungstest fur 4. and 5. Klassen – HST 4/5.* Sixth-grade students were assessed using the *Hamburger Schulleistungstest fur 6. and 7. Klassen – HST 6/7.* Both tests have been used successfully in the past, including a longitudinal school achievement census conducted in the City of Hamburg (Lehmann, Peek, & Gaensfuss, 1997; Lehmann, Gaensfuss, & Peek, 1999). This approach allows comprehensive comparisons of the students in the present study with those of the Hamburg study.

The *HST 4/5* includes a wide array of mathematical competencies. Topics include numerical and digital values, the relationship between verbal and non-verbal representations of numbers, basic arithmetic operations, histograms, measurement, and computation. The *HST 6/7* focuses on arithmetic, geometry, and algebra.

Both tests use a multiple-choice format with four response categories. The time to solve all problems without use of a calculator was 45 minutes. The test used two pseudo-parallel forms that differed only in the order of items and response categories. At post-test, the students received the parallel form they had not done at pre-test.

Intelligence Test. In order to control for individual differences in learning ability, the mathematics test was complemented by an adapted short version of Cattell's non-verbal *Culture Fair Intelligence Test – CFT 20* (Weiss, 1998). The test aims to measure "fluid intelligence," which includes aspects of reasoning abilities. The items are organized into four sub-tests: Continuation of Sequences, Classifications, Matrices, and Topological Reasoning. The format of this standardized test allows it to be virtually independent of the command of the language of instruction, as well as of substantive subject-matter knowledge. In short, it helps identify discrepancies between a student's cognitive resources and his/her achievement in the subject. The adapted short version requires about 40 minutes to complete. Like the *HST,* the *CFT 20* also was administered in the Hamburg longitudinal study.

Student Questionnaire. Students were asked for their attitudes and beliefs regarding mathematics, including their self-efficacy and interest in the subject. The questionnaire was also used to collect information about the educational environment at home. In addition to social background characteristics, such as the language spoken in the home, parents' education, and other indicators, information about resources specifically relevant to education, such as access to books, computers, the Internet, and places to study, was collected. Students in experimental classrooms were asked additional questions about their experiences with Accelerated Math.

Teacher Questionnaire. Teachers were asked to characterize mathematics instruction in their classrooms. They were also asked for their general attitudes toward their school and instructional strategies, as well as their satisfaction with work and perceived stress and pressure on the job. Teachers who had implemented Accelerated Math in their classrooms were asked additional questions about their experiences with the system.

SAMPLING STRUCTUCE: SCHOOLS AND CLASSES The NRW education ministry selected schools to participate in the study that would represent a wide range of student abilities. A total of 15 schools participated in the pretest; 14 schools participated in post-testing. Because one elementary school decided to discontinue its participation in the study, the evaluation is based on only 14 schools. As a result, four primary schools serving fourth-grade students participated, with one Accelerated Math class and one control class each for a total of eight classrooms. A total of 10 secondary schools participated, among them three *Hauptschulen* (Basic), three *Realschulen* (Intermediate), two *Gesamtschulen* (Comprehensive) and two *Gymnasium* (Academic) with 18 Accelerated Math classrooms and 21 control classrooms[1]. A total of 47 classrooms with 1,243 students participated continuously in the study.

As previously mentioned, the original sample experienced a small amount of attrition over the course of the study. Originally, five primary schools had been identified to participate, but one discontinued participation at the beginning of the experiment, resulting in the loss of that school and its classes (one Accelerated Math class and one control class) from the sample. This school participated in the pre-test, but was not included in subsequent analyses. In addition, due to technical difficulties encountered early in the experiment, one teacher who had originally been assigned to implement Accelerated Math was not able to, and was thus redefined as a control class. This resulted in a distortion of the test design with a higher number of control classes. The final distribution of Accelerated Math and control classes by school type, grade level, and class are summarized in Table 1 (page 12).

Pre-testing was completed in February and March of 2004, and the post-testing was completed in June and July of 2004. Students in both Accelerated Math and control classrooms had a minimum of four months of instruction between pre- and post-test.

[1]In the German educational system, children in grades 1–4 attend elementary school (*Grundschule*). Following fourth grade, students are sent to one of three types of schools depending on their academic performance and their family's preference: *Hauptschule*, in which subjects are taught at a relatively slower pace and ultimately leads students to enroll in vocational schools; *Realschule*, which often leads to vocational or higher vocational schools; or *Gymnasium*, which prepares students for university or combination academic-vocational degrees. Many German states, including North Rhine-Westphalia, also have the *Gesamtschule*, or combined school, which enrolls students of all ability levels. Source: Ashwill, M.A., Foraker, W., Nerison-Low, R., Milotich, M., & Milotich, U. (1999). *The educational system in Germany: Case study findings.* Washington, DC: U.S. Department of Education. Available online: <http://www.ed.gov/PDFDocs/GermanCaseStudy.pdf>.

Table 1: Number of Classrooms by Grade, School Type, and Participation Status

School Type	Accelerated Math		Control Group	
	Classes	Students	Classes	Students
Primary Schools (Grade 4)	4	92	4	105
Secondary Schools (Grade 5)				
• *Hauptschule (Basic)*	3	60	3	62
• *Realschule (Intermediate)*	2	61	2	62
• *Gymnasium (Academic)*	2	62	2	62
• *Gesamtschule (Comprehensive)*	2	56	2	55
Secondary Schools (Grade 6)				
• *Hauptschule (Basic)*	2	45	4	90
• *Realschule (Intermediate)*	3	80	4	111
• *Gymnasium (Academic)*	2	64	2	63
• *Gesamtschule (Comprehensive)*	2	57	2	56
Total	22	577	25	666

Student Characteristics at the Beginning of the Study

Fourth Grade. Fourth-grade classes in the study were characterized by an unusually high level of nonverbal intelligence, by higher-than-average performance on the mathematics achievement pre-test, and by cultural and social environments that appeared to be conducive to learning. The control group in particular showed higher levels of performance on the pre-test intelligence and mathematics measures compared to the Accelerated Math group.

Combined, the fourth-grade students scored about two raw points above the mean of the reference sample from the Hamburg longitudinal study on the *CFT 20*, which actually administered the test at the beginning of grade five, i.e., half a year later than the current study. Students from the control-group classes scored slightly higher on the *CFT 20* than the average of the students in the Accelerated Math classes.

Like their performance on the intelligence test, fourth-grade students in the study exhibited a relatively high level of proficiency on the *HST 4/5* mathematics achievement test. To evaluate individual mathematical ability, the raw *HST* scores were converted to proficiency scores using the one-dimensional Rasch Model based on Item Response Theory (IRT). Using proficiency scores, researchers can determine achievement gains. The parameters used in this context allow for a comparison of the study results with other national performance studies, including the aforementioned Hamburg longitudinal study and the *Berliner Studie Element* (Lehmann & Nikolova, 2004). The fourth-grade students in this study had pre-test results that were clearly above reference values for students in both Hamburg and Berlin.

The control students scored higher on the pre-test than the average test result of the Accelerated Math group by one-half standard deviation (116 to 103 proficiency score points). At the classroom level, the differences between both groups were even more apparent. The classroom with the lowest mean proficiency score achieved about one-half of a standard deviation below the grand mean for all fourth-grade classes, while the classroom with the highest mean score performed at a mean level of almost two-thirds of a standard deviation above the grand mean.

The results of the student questionnaire confirmed that the fourth-graders in the study came from backgrounds that are conducive to learning. These students had good access to resources relevant to education. In addition, only the percentage of students from immigrant families (approx. 17 percent) was far below the national average. Of the immigrant group, about half reported regularly speaking German at home, which implies a high degree of cultural integration and underlines the positive selection of elementary schools in this study.

Since the participation of schools and teachers in the study was voluntary, one may assume that schools with favorable patterns of motivation, greater interest in adopting innovative practices, and relatively higher levels of mathematics achievement were more likely to participate than others and that there was a tendency within these schools for the higher achieving classrooms to join the sample.

Fifth Grade. Similar to the fourth-grade students in the study, the fifth-grade students were characterized by a level of nonverbal intelligence that was above average, by higher-than-average performance on the mathematics achievement pre-test, and by cultural and social environments that appeared to be conducive to learning. But unlike grade four, the grade-five Accelerated Math group showed slightly higher levels of performance on the pre-test intelligence and mathematics measures compared with the control group.

On the *CFT 20* intelligence test, fifth-grade students scored about two raw points higher than the adjusted age norm in the *CFT 20* calibration sample, and about three raw points higher than fifth-graders from the Hamburg longitudinal study. The *CFT 20* scores among fifth-graders were more widely distributed than the fourth-graders'. Accelerated Math students displayed higher cognitive abilities than those of the control group.

With respect to the mathematical abilities of participants from the fifth grade, achievement also exceeds the reference values from the Hamburg longitudinal study. The Accelerated Math group's performance was slightly higher than the control, by about one proficiency point (117 to 116).

Via the questionnaire, fifth-grade students were asked about their home environments. Like the fourth-graders, they described home environments shown by various empirical studies to have a significant effect on academic achievement. About 86 percent reported having a room of their own, about three-quarters had access to a dictionary, encyclopedia or books on specific subjects at home, and more than half had a computer of their own. Again, the survey showed a markedly small percentage of students from immigrant families, which is lower than the average percentage for all students in NRW if measured by the language spoken in the home. About one-third of these students speak primarily German, which is conducive to learning in children from immigrant families.

Sixth Grade. Contrary to what was observed in grades four and five, the average nonverbal reasoning abilities in grade six were very close to the adjusted age norm in the *CFT 20* calibration sample. The scores of the Accelerated Math and control groups were almost identical to one another.

There was no significant difference in mathematics pre-test achievement between Accelerated Math and control groups. To reach this conclusion, it should be noted that data for *Hauptschule* and *Realschule* students were weighted because the distribution of Accelerated Math and control classes had changed.

Just as in the fourth and fifth grades, the sixth-grade questionnaire indicated that a majority of students had educationally relevant materials and resources at home, such as a room of their own (85 percent), a desk of their own (91 percent), dictionaries or encyclopedias of their own (79 percent), and a computer of their own (65 percent). About 20 percent of sixth-graders came from immigrant families, with about half of those speaking German regularly at home.

RESULTS BY GRADE

Fourth Grade. Overall, if the average mathematics proficiency score at pre-test (mean=109.9, SD=25.0) is compared with that of post-test (mean=122.4, SD=24.9), one can see that there was an increase of approximately one-half a standard deviation for the entire fourth-grade group (see Table 2). This corresponds to marked and above-average achievement gains within a time period of approximately four months.

Table 2: Mean Mathematics Proficiency at the Beginning and End of the Experiment, by Experimental Status and Class, Grade 4

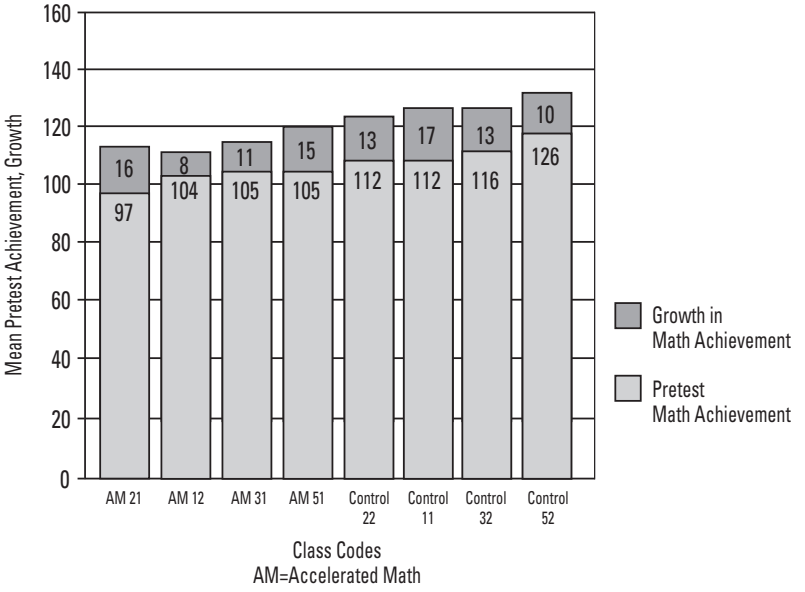
Status	Class Code	Pretest Mean (IRT scores)	Pretest Standard Deviation	Post-Test Mean (IRT scores)	Post-Test Standard Deviation	Pre-Post-Test Difference	Effect Size	Number of Students (pre and post)
Accelerated Math	12	103.87	16.27	109.86	21.25	5.99	0.37	22
	21	97.49	18.58	113.32	18.49	15.83	0.85	25
	31	106.79	27.68	117.27	20.19	10.48	0.38	17
	51	104.83	35.69	120.80	28.36	15.97	0.45	20
	Total	*102.82*	*24.90*	*115.00*	*22.24*	*12.16*	*0.49*	*84*
Control	11	112.12	28.96	128.92	28.27	16.80	0.58	28
	22	111.36	19.78	124.66	22.25	13.30	0.67	28
	32	115.86	19.30	128.11	22.41	12.25	0.63	16
	52	126.27	20.91	134.76	27.38	8.49	0.41	25
	Total	*116.12*	*23.46*	*129.07*	*25.35*	*12.95*	*0.55*	*97*
Accelerated Math and Control	*Total*	*109.86*	*24.98*	*122.44*	*24.89*	*12.58*	*0.50*	*181*

At first glance, there does not seem to be much difference between Accelerated Math and control classes with respect to gains in mathematics proficiency. However, there is considerable variation at the class level, as shown in Table 2 (page 16) and in Figure 1 (page 18).

A comparison between Accelerated Math groups shows significant variation between the achievement gains from pre- to post-test. In this context, we evaluated whether some of this variation in growth may be due in part to the extent to which teachers actually used Accelerated Math in their classrooms, or if the variation is caused primarily by differences between teachers and learning contexts. In order to measure the intensity of utilization of Accelerated Math, log data on individual, student-level usage were aggregated to the class level. User groups were defined according to the average number of problems attempted by a given class. Four implementation groups were distinguished empirically—minimal, partial, regular, and intensive. Ultimately, only the distinction between intensive usage against all other forms proved to be significant.

Among fourth-grade classes, the strongest performance occurred in the class that used Accelerated Math most intensively. Figure 1 depicts the mean increments in mathematics proficiency between the pre- and the post-test achievement by class. The Accelerated Math class coded #21 was the intensive class, and it achieved an increase of 0.85 standard deviation, the largest achievement gain in mathematical abilities.

Figure 1: Mathematics Proficiency in the Initial and the Final Data Collection, by Class and Experimental Status, Grade 4



A multiple-regression analysis was conducted to determine which characteristics are most important in predicting the post-test proficiency scores. Pre-test performance turned out to be the strongest predictor of post-test score. Other important predictors include students' initial math-related self-efficacy, nonverbal reasoning ability, and the frequency with which German is used as the home language. There were not a sufficient number of fourth-grade classrooms in this study to determine whether or not the intensity of Accelerated Math implementation was a significant predictor.

Fifth Grade. Substantial mathematics proficiency gains were again observed both in Accelerated Math and control classes, but these gains were about twice as large for Accelerated Math classes as control classes. As shown in Table 3 (page 19), Accelerated Math classes achieved an average increase from pre- to post-test of nine proficiency points, or about one-third of a standard deviation—an amazing growth, given the short duration of the experiment. This compares with an increase for the control classes of 5 proficiency points, or about 19 percent of a standard deviation—a respectable rate of progress compared to average achievement gains in comparable grade levels and observation periods.

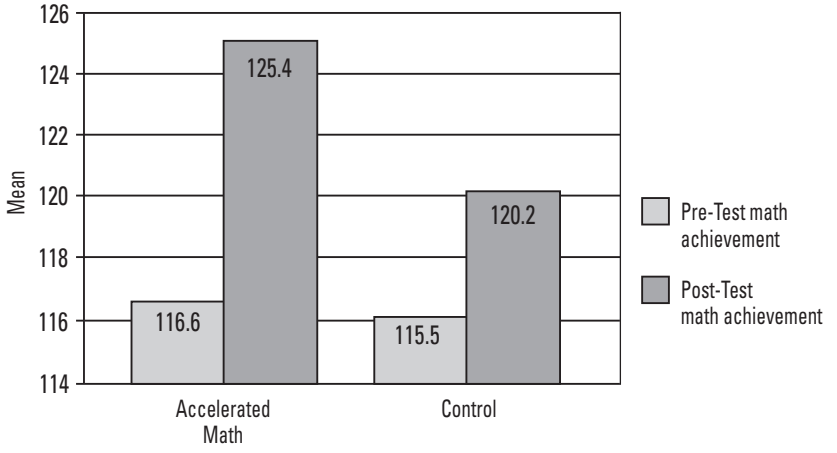
The findings can be summarized as follows: Over a period of one half of a school year, Accelerated Math classes observed an average growth that was equivalent to the typical *annual* growth reported in relevant reference groups (see Lehmann, Gaensfuss & Peek, 1999; for TIMSS, see Baumert et al., 2000). The rate of achievement growth in the present study is therefore quite remarkable given the short observation period.

Table 3: Mean Mathematics Proficiency at the Beginning and End of the Experiment, by Experimental Status, School Type, and Class, Grade 5

Status	School Track	Class Code	Pretest Mean (IRT scores)	Pretest Standard Deviation	Post-Test Mean (IRT scores)	Post-Test Standard Deviation	Pre-Post-Test Difference	Effect Size	Number of Students (pre and post)
Accelerated Math	*Hauptschule* (Basic)	62	96.06	15.93	99.52	17.54	3.46	0.22	10
		72	107.45	18.21	120.95	19.93	13.50	0.74	22
		81	99.30	14.46	108.91	19.67	9.61	0.66	18
	Realschule (Intermediate)	101	116.92	13.75	122.66	19.86	5.74	0.42	30
		111	106.19	23.84	122.63	17.45	16.44	0.69	28
	Gymnasium (Academic)	122	131.44	21.37	144.32	18.10	12.88	0.60	30
		131	143.71	22.62	157.14	21.82	13.43	0.59	30
	Gesamtschule (Comprehensive)	142	97.08	16.46	102.65	20.24	5.57	0.34	23
		151	123.49	18.28	126.31	21.71	2.82	0.15	28
		Total	*116.64*	*24.42*	*125.43*	*26.15*	*8.79*	*0.36*	*219*
Control	*Hauptschule* (Basic)	61	99.89	13.58	104.32	15.91	4.43	0.33	14
		71	96.74	16.87	107.46	19.13	10.72	0.64	22
		82	90.81	18.18	93.66	19.47	2.85	0.16	20
	Realschule (Intermediate)	102	123.93	29.49	132.04	20.14	8.11	0.28	31
		112	124.07	17.63	120.99	17.97	–3.08	–0.17	28
	Gymnasium (Academic)	121	131.72	22.60	138.63	18.93	6.91	0.31	28
		132	140.20	17.84	142.76	17.45	2.56	0.14	30
	Gesamtschule (Comprehensive)	141	96.79	15.08	102.44	19.01	5.65	0.37	20
		152	110.36	17.83	114.76	22.08	4.40	0.25	29
		Total	*115.45*	*25.77*	*120.18*	*24.75*	*4.73*	*0.19*	*222*
Accelerated Math and Control	*Hauptschule* (Basic)		98.52	17.08	106.37	20.51	7.85	0.46	106
	Realschule (Intermediate)		117.81	22.97	124.63	19.18	6.82	0.30	117
	Gymnasium (Academic)		136.85	21.59	145.75	20.12	8.90	0.41	118
	Gesamtschule (Comprehensive)		108.13	20.22	112.47	22.88	4.34	0.21	100
		Total	*116.00*	*25.08*	*122.79*	*25.56*	*6.79*	*0.27*	*441*

Figure 2 (page 20) demonstrates the difference between the Accelerated Math and the control group in terms of average proficiency gain. Based on nearly equivalent pre-test levels, the group of students that used Accelerated Math attained, on average, a clearly higher achievement level than the control group.

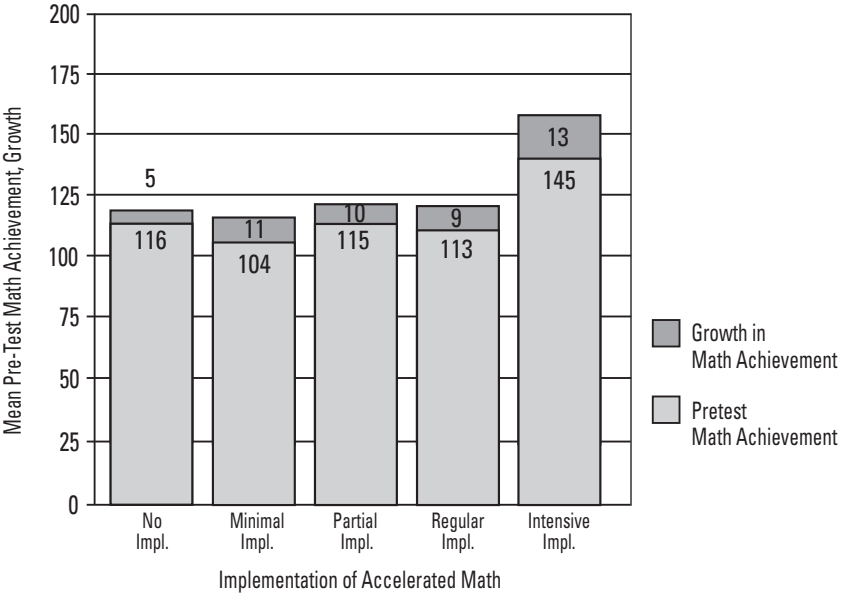
Figure 2: Mathematics Proficiency in the Initial and the Final Data Collection, by Experimental Status, Grade 5



As with grade four, there was substantial variance between classes in terms of the intensity with which Accelerated Math was implemented. Specifically, two of the nine treatment classes made only minimal use of the system and two more only used it partially. Four classes can be described as having used it regularly, and only one intensively.

If average proficiency gains are considered in their relationship to the level of utilization of Accelerated Math, the superior proficiency gains in the group with intensive exposure become apparent (see Figure 3 on page 21). If the non-random nature of this difference were to be tested statistically, greater numbers of intensively exposed classrooms would obviously be required. Unfortunately, under the constraints of the present experiment, this could not be attained in any of the three grades investigated.

Figure 3: Mathematics Proficiency in the Initial and the Final Data Collection by the Intensity of Utilizing Accelerated Math, Grade 5



As with the fourth-grade results, a multiple regression was conducted using the fifth-grade data to determine which characteristics are most important in predicting the post-test proficiency scores. Again, pre-test achievement emerged as the strongest predictor of the post-test scores. Other significant independent contributions include intensive utilization of Accelerated Math, followed by nonverbal reasoning ability, and selected characteristics of instruction.

Sixth Grade. As observed with the fourth-grade and fifth-grade data, the overall increase in mathematics proficiency for all groups was clearly higher than what has been reported in comparable achievement studies. This increase is remarkable given the relatively short time frame in which the study was conducted. The increase of mathematics proficiency within four months on the order of 36 percent of a standard deviation is clearly higher than what has been reported in comparable achievement studies (for TIMSS, see Baumert et al., 2000; for the Hamburg longitudinal census, see Lehmann, Gaensfuss, & Peek, 1999). In Hamburg, the mean growth from the beginning of grade five to the beginning of grade seven was 0.68 standard deviations, or 0.34 standard deviations per year. As opposed to these figures, both the Accelerated Math and control classrooms achieved a larger increment in a considerably shorter period of time.

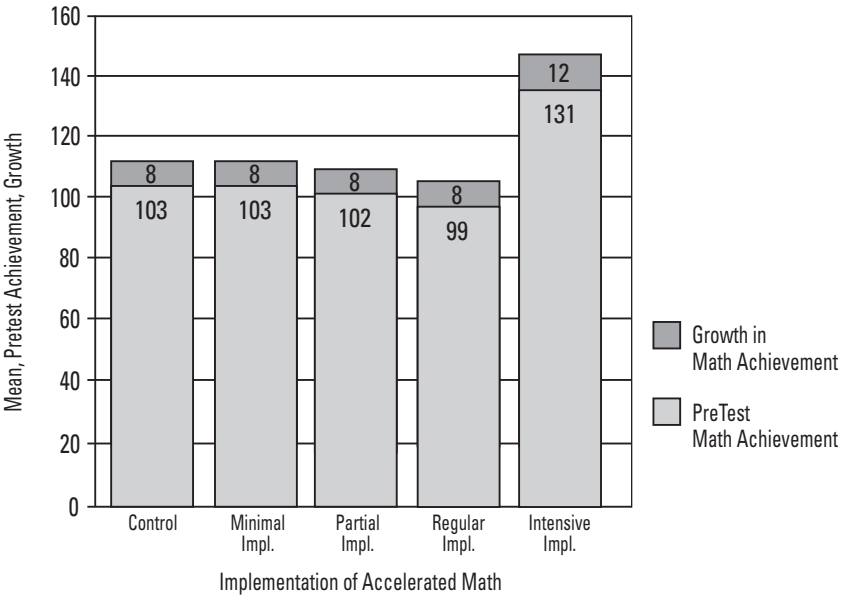
Between Accelerated Math and control classes, the level of achievement gain was approximately equivalent. Both Accelerated Math and control classes achieved a gain of about eight proficiency points. Table 4 shows the overall proficiency values, as well as between-class differences, which are quite noticeable in places.

Table 4: Mean Mathematics Proficiency at the Beginning and End of the Experiment, by Experimental Status, School Type, and Class, Grade 6

Status	School Track	Class Code	Pretest Mean (IRT scores)	Pretest Standard Deviation	Post-Test Mean (IRT scores)	Post-Test Standard Deviation	Pre-Post-Test Difference	Effect Size	Number of Students (pre and post)
Accelerated Math	*Hauptschule* (Basic)	64	85.63	17.34	94.80	15.68	9.17	0.53	13
		83	90.35	18.34	92.66	18.14	2.31	0.13	18
	Realschule (Intermediate)	94	101.79	14.48	113.65	12.66	11.86	0.82	23
		104	104.45	6.78	115.97	15.68	11.52	1.70	25
		113	104.13	14.69	109.15	14.22	5.02	0.34	24
	Gymnasium (Academic)	123	119.35	17.12	133.40	21.59	14.05	0.82	31
		133	130.75	20.45	142.71	21.39	11.96	0.58	30
	Gesamtschule (Comprehensive)	144	87.07	15.62	87.35	15.76	0.28	0.02	24
		153	108.08	17.38	111.09	15.81	3.01	0.19	27
	Total		*103.75*	*21.27*	*111.48*	*24.11*	*7.73*	*0.36*	*215*
Control	*Hauptschule* (Basic)	63	88.08	11.44	93.91	13.47	5.83	0.51	14
		73	87.36	12.39	89.59	14.39	2.23	0.18	20
		74	93.37	16.90	103.82	15.77	10.45	0.62	21
		84	90.75	25.11	103.72	19.05	12.97	0.52	20
	Realschule (Intermediate)	92	96.47	20.10	106.96	20.47	10.49	0.52	27
		93	87.47	15.44	102.23	17.16	14.76	0.96	27
		103	127.58	16.20	137.94	17.41	10.36	0.64	27
		114	103.36	16.64	106.00	14.40	2.64	0.16	25
	Gymnasium (Academic)	124	119.26	16.76	125.63	24.48	6.37	0.38	32
		134	123.38	21.65	133.28	25.39	9.90	0.46	29
	Gesamtschule (Comprehensive)	143	85.83	11.17	88.60	12.79	2.77	0.25	24
		154	110.70	15.85	116.15	20.90	5.45	0.34	28
	Total		*103.85*	*22.64*	*111.75*	*24.56*	*7.90*	*0.35*	*294*
Accelerated Math and Control	*Hauptschule* (Basic)	Total	89.12	17.53	95.66	16.96	6.54	0.37	106
	Realschule (Intermediate)	Total	103.59	18.21	113.02	18.81	9.43	0.52	178
	Gymnasium (Academic)	Total	123.09	19.39	133.56	23.78	10.47	0.54	122
	Gesamtschule (Comprehensive)	Total	98.46	18.98	101.88	20.99	3.42	0.18	103
	Total		*103.80*	*21.94*	*111.61*	*24.31*	*7.81*	*0.36*	*509*

Figure 4 (page 23) demonstrates the average proficiency growth in sixth-grade Accelerated Math and control classes that were divided into four groups according to the degree to which Accelerated Math was implemented.

Figure 4: Mathematics Proficiency in the Initial and the Final Data Collection, by Experimental Status, Depending on the Intensity of Utilizing Accelerated Math, Grade 6



While the control group and classes where Accelerated Math was used only experienced an average gain of eight proficiency score points, there were greater increments in the group of intensive Accelerated Math users. Admittedly, this group of intensive users encompassed only one class. This observation, however, underscores the point that further research is needed with a sufficiently large number of classes where the program is appropriately implemented.

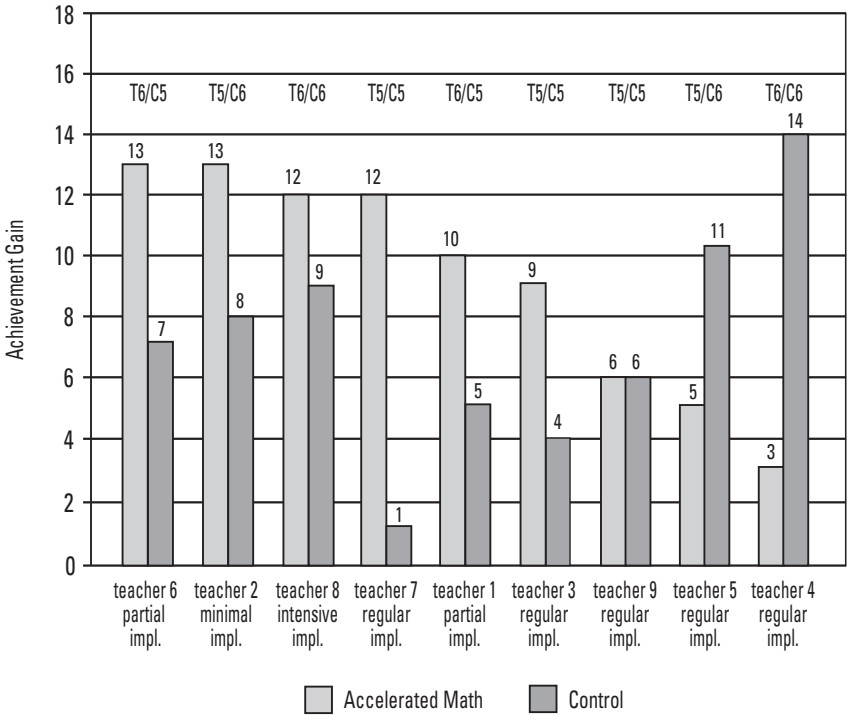
As in the case of grades four and five, a multiple-regression analysis was conducted for grade six in order to ascertain which variables have had a significant independent impact on post-test achievement. Significant predictors included mathematics proficiency as measured in the pretest, nonverbal reasoning ability (*CFT 20* scores), selected social background factors, math-related self-concept, student perceptions of mathematics instruction, and the intensity of using Accelerated Math in class.

Selected Case Studeis: Teachers Who Taught both Accelerated Math and Control Classes

A number of case studies show that cognitive gains are highly dependent on the learning context and the learning opportunities as provided by the individual teacher (e.g., Ditton, 1997). The original study design had called for the same teachers teaching *both* in an Accelerated Math class *and* a control class in order to control for teacher personality and didactic style. Although this could not be implemented in all schools, there were a total of nine teachers who taught, in separate classrooms, both with Accelerated Math and following their traditional modes of teaching. Four of these nine teachers taught both groups at the same grade level (treatment and control class either both grade five or both grade six). The remaining five have taught one of the groups in grade five and the other in grade six.

From the analysis we conclude that *six of the nine teachers attained higher gains in their Accelerated Math classes.* In two cases, the control classes appear to have been more successful, and in one case there was no difference between Accelerated Math and the control group. Figure 5 (page 25) demonstrates the proficiency gains in the Accelerated Math and control classes that were taught by the same teacher.

Figure 5: Differential Gains in Accelerated Math and Control Groups with Identical Teacher



Teacher and Student Evaluations of Accelerated Math

Of the nine teachers who taught in both Accelerated Math and control classes, six had an overall positive assessment of the system, underlining primarily its diagnostic ability and its opportunities for individualizing instruction. Two had a neutral opinion, and only one of the nine teachers expressed a critical opinion.

Across all teachers who used Accelerated Math, the majority expressed positive views of the system. One of the best-liked features was that students receive a multitude of appropriate math problems that provide ample opportunities for practice and reinforcement. Other advantages of Accelerated Math, according to the teachers, included individualized support for students and the program's ability to assist teachers in monitoring individual student progress without significantly greater time and effort. In addition, a majority of teachers reported that students using Accelerated Math displayed increased levels of interest in mathematics.

When asked whether or not they would prefer to return to their old teaching methods, most (65 percent) indicated that they preferred using Accelerated Math while the rest (35 percent) preferred a return to their conventional teaching techniques.

Teachers who used Accelerated Math completed a survey that asked them to report their level of agreement or disagreement with several statements regarding Accelerated Math. Both positive and negative statements regarding Accelerated Math were included in the survey. The statements having the strongest level of agreement were all positive. They are as follows, in order of agreement:

- I liked the fact that students could practice that much;
- The new approach [Accelerated Math] motivated our students well;
- The new approach [Accelerated Math] enabled the students to determine their pace of learning;
- Individual instruction is possible with this new approach [Accelerated Math]; and
- The students have a greater interest with this approach [Accelerated Math].

Students in Accelerated Math classrooms were asked to complete a similar survey in which they were given a series of positive and negative statements regarding the system. Similar to the teachers, students most strongly agreed with positive statements regarding Accelerated Math. The statements having the strongest level of agreement were as follows, in order of agreement:

- I enjoyed working with this new approach in math [Accelerated Math];
- I liked that I could practice a lot;
- With this new method [Accelerated Math] I can judge what goals I achieved;
- I like the new method [Accelerated Math] better than the way the lessons were before; and
- I like that I could decide how fast I would learn.

Conclusion

Implementation of Accelerated Math on an experimental basis in grades four, five, and six from 14 NRW schools had mixed effects overall. In grade five, students using Accelerated Math demonstrated pre-post achievement gains that were about double that of students in control classes using traditional methods. In grades four and six, however, there was little difference in the gains produced by Accelerated Math and control students. Overall though, both Accelerated Math and control students had unusually high gains over a relatively short period of instruction (four months) when compared with national and regional mathematics achievement data.

The extent to which teachers used Accelerated Math in their classrooms was assessed, and across all grades, the classrooms in which the Accelerated Math program was fully implemented (i.e., used intensively) produced the largest gains in mathematics achievement. Classrooms in which Accelerated Math was used to a lesser extent achieved about the same gains as control classes. However, due to the relatively small number of classes that used the system intensively, further analyses with a sufficient number of classes in which the program was fully implemented would be needed.

The original study design called for the same teachers to teach both in an Accelerated Math class and a control class to control for teacher characteristics. While this design proved impractical in some schools, nine teachers did teach both groups, allowing us to control for teacher characteristics. In six out of these nine cases, achievement gains in the Accelerated Math classes were higher than those in the control group.

When surveyed about their experiences using Accelerated Math, teachers described it as an interesting new approach to teaching and learning mathematics. They rated highly its abilities to generate appropriate work for students and to help them to systematically monitor individual student progress. Most also indicated that levels of student motivation and interest in mathematics increased after being exposed to Accelerated Math.

BIBLIOGRAPHY OF FULL REPORT

Baumert, J., Köller, O., Lehrke, M. & Brockmann, J. (2000). Anlage und Druchführung der Dritten Internationalen Mathematik- und Naturwissenschaftsstudie zur Sekundarstufe II (TIMSS/III) – Technische Grundlagen. In Baumert, J., Bos, W. & Lehmann, R. H. (Hrsg.), *Dritte Internationalen Mathematik- und Naturwissenschaftsstudie. Mathematische und naturwissenschaftliche Bildung am Ende der Schullaufbahn.* Opladen: Leske und Budrich, 31–84.

Bos, W. & Pietsch, M. (2004). Erste Ergebnisse aus KESS 4 – Kurzbericht. http://www.erzwiss.uni-hanburg.de/Kess/kurzbericht.pdf.

Cattel, R. B. (1960). Culture Fair Intelligence Test, Scale 2 (Handbuch). 3. Auflage, III., IPAT.

Fischer, G.H. & Molenaar, I. W. (1995). *Rasch models – Foundations, recent developments, and applications.* New York: Springer.

Ditton, H. (1997). Wirkung und Wirksamkeit der Einzelschule – Analysen der Bedeutsam-keit der verschiedenen Ebenen des Schulsystems. In Lehmann, R. H., Venter, G., Buer, J. van, Seeber, S. & Peek, R. (Hrsg.), Erweiterte Autonomie für Schule – Bildungscontrolling und Evaluation. Studien zur Wirtschafts- und Erwachsenenpädagogik aus der Humboldt-Universität zu Berlin. Band 13.2. Abschlussband zur gleichnamigen Sommerakademie vom 31. August bis 6. September 1997 in Ungarn. Ny_regyháza-Berlin.

Ditton, H. (2001). Skalendokumentationen zum DFG-Projekt "Bildungsqualität von Schule und Unterricht." www.quassu.net/seite4.html.

Lehmann, R. H., Peek, R. & Gaensfuss, R. (1997). *Aspekte der Lernausgangslage von Schülerinnen und Schülern der fünften Klassen an Hamburger Schulen.* Behörde für Schule, Jugend und Berufsbildung, Amt für Schule, Hamburg.

Lehmann, R. H., Gaensfuss, R. & Peek, R. (1999). *Aspekte der Lernausgangslage und der Lernentwicklung. Ergebnisse der Längsschnittstudie für die Klassenstufe 7.* Behörde für Schule, Jugend und Berufsbildung, Amt für Schule, Hamburg.

Lehmann, R. H., Peek, R., Gaensfuss, R. & Hussfeld, V. (2001). *Aspekte der Lernausgangs-lage und der Lernentwicklung. Ergebnisse der Längsschnittstudie für die Klassenstufe 9.* Behörde für Schule, Jugend und Berufsbildung, Amt für Schule, Hamburg.

Lehmann, R. H., & Nikolova, R. (2004). Erhebung zum Lese- und Mathematikverständnis, Entwicklungen in den Jahrgangsstufen 4 bis 6 in Berlin. http://www. Senbjs.berlin.de/ bildung/qualitaetssicherung/ element_ersterbericht.pdf.

Weiss, R. H. (1998). Grundintelligenztest Skala 2, CFT 20. Handanweisung. Göttingen: Hogrefe.

RENAISSANCE LEARNING Renaissance Learning is a world leader in learning information system (LIS) technology and online computer assessments for K–12 schools. Founded in 1986, Renaissance Learning employs 1,000 people at five U.S. locations and four international sites—the United Kingdom, India, Australia, and Canada.

More than 67,000 schools, 500,000 teachers, and 15 million students use Renaissance LISs daily. By providing instructional leaders with more and better information on student progress and achievement, Renaissance LISs support and enhance virtually any curriculum and instructional program. More than 150 Renaissance consultants provide professional development and consulting services that show educators how to best use computerized information systems to improve instructional decisions.

Renaissance technology includes such well-known Tier 1 LISs as Accelerated Reader, Accelerated Math, and Accelerated Writer; Tier 2 LISs such as STAR Reading, STAR Early Literacy, STAR Math, and StandardsMaster; and Renaissance Place, the web-based results management system for instructional leaders.

PO Box 8036
Wisconsin Rapids, WI 54495-8036
(866) 846-7323
www.renlearn.com

L2178.0405.SW.1.5M