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The Link between Teaching Methods and Achievement in Math in Computer-Assisted Elementary Schools

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Abstract

This study compares the effect of frontal teaching methods on achievement levels in math to those of alternative teaching methods in elementary schools where classroom teaching is reinforced with computer sessions. The study was conducted in two urban, elementary schools in underprivileged areas and involved 479 students in grades 4, 5 and 6 and 18 teachers 9 who used the frontal method and 9 who used the alternative method. Progress was checked while accounting for students' age and level. Significant differences between the two methods were found: Students in the alternative method progressed more during the year than those in the frontal method. Furthermore, the lead of alternative students mostly increased with age and grade level, while most frontal students remained at their level. District tests conducted two years after data collection for the study further corroborated the study findings. The results indicate that the teaching method is a decisive factor in student achievement in math and that full coordination of classroom teaching with computer practice is of prime importance. This requires a change from the traditional teaching methods, incorporating attention to the differing needs and achievements of students.

Keywords

Alternative Teaching, Achievement Mathematics, Computer-Assisted, Elementary School, Teaching Methods, Mathematics Education, Technology and Education

1. Introduction and Theoretical Background

The rationale for this study was the low level of achievement in mathematics found to be prevalent in the elementary school system in Israel. Less than 50% of

students achieve a passing mark in math in the lower grades and only approximately 14% of students graduate as science majors. Only a small percentage of high school students graduate with an understanding of science and math, despite recent technological developments in education (Harari, 1992). International data show a decline in math and science studies. According to Schon (1983), teachers should accept responsibility for their students' achievements. A large proportion of teachers do not have proper training in teaching these subjects (Raloff, 1988; Shamos, 1988), especially in remote and underprivileged neighborhoods (Harari, 1992; Raloff, 1988).

Most of the participants in this study were underprivileged children who, due to social constraints, do not attain the achievement levels attainable under normal conditions, nor even the average achievement levels of the country. They are normally deprived access to appropriate educational institutions and usually cannot benefit fully from those institutions they can access. They generally lack school preparation and are deficient in perception, speech, sorting, abstraction, reading and conceptual abilities. This lacuna gradually increases with time, often resulting in failure to graduate, thus perpetuating their inferior status beyond school into the realms of employment and personal life. The Ministry of Education's inability to provide enrichment and cultivate knowledge for children from disadvantaged communities widens the gap between excellence and backwardness and impairs the ability of weaker populations to advance, develop and cope with the modern world (Iram & Schmida, 1993).

The equal opportunity gap between the underprivileged and the well-off is clearly represented by computers. Disadvantaged children are much less likely to access computer-assisted learning than the well-off. Sutton (1991) reports that about 32% of students in affluent schools participated in computer-assisted learning, compared to only 17% of underprivileged students. The computer is highly regarded for its contribution to improving the learning capacity and strengthening the confidence of disadvantaged students and preparing them for integration into the modern world. In addition, researchers have emphasized the importance of learning for growth—so important to this population (Louden, Rohl, & Hopkins, 2008).

1.1. Alternative Teaching Methods

Alternative methods of teaching differ from each other in organizational and pedagogical aspects, but they all stem from the point of view that one must diversify teaching methods, activate and engage students in the learning process, integrate instructional technologies adapted to the different needs and levels of the heterogeneous classroom, and address the psychological and epistemological aspect (which examines the question: "What is the knowledge that we want to instill in school?") This approach, which serves as a basis for creating models for teaching mathematics, takes into account the ability and limitations of the child, but also the specific skills that these models aim to impart.

In many alternative learning environments, computers are employed to help students progress (Nesher, 1986; Cosgrove & Osborne, 1985). Researchers identified various components of interaction in alternative learning environments that encourage discussion and dialogue, fostering learning. For example, asking questions that provoke productive discussion and presenting complex issues for discussion (Kreijns, Kirschner, & Jochems, 2003). In addition, researchers identified a variety of strategies for responding to students' ideas, including echoing the ideas, reformulating them, and perfecting and expanding students' thinking through discussion (Grossman, Hammerness, & McDonald, 2009). Technology-based, alternative learning environments inspire a combination of individual or group activity with the computer and class discussion about thinking and learning outcomes. It is important to focus on how to learn, not only what to learn (Bielaczyc, 2006; Järvenoja, & Järvelä, 2009).

In alternative teaching, awareness of the unique needs of each student induces instruction both to the entire class and in small groups (Hertz-Lazarowitz et al., 1989; Shaftiya, 1989). According to Hertz-Lazarowitz, & Fuchs based on the methodological attitude supported by renowned thinkers and psychologists, including Piaget (1972), these approaches allow more effective learning processes, flexible instruction with many choices in the hands of the teacher, and the possibility to match the learning processes to the academic and emotional Caspi, M that teachers play an important role in modeling approaches and ways of thinking in the subject, building familiarity between peers and exposing them to each other's thinking (Kreijns et al., 2003) and proposing worthy goals and conduct conducive to achieving the educational goals in different subjects (Reznitskaya & Gregory, 2013).

1.2. The Computer as a Tool for Improving Math Teaching

Harari (1992) shows that incorporating computers in the teaching contributes greatly to the learning process and recommends, inter alia, conducting "a comprehensive campaign to introduce the use of computers in all educational institutions at all levels and in all subjects" (p. 7). Osin, Nesher and Ram (1994) note that "teaching mathematics in elementary schools using computers improves student achievement compared to conventional teaching methods" (p. 15). Campbell (1988), Bielaczyc (2001) and Mevarech (1985) treat the subject favorably and believe that the use of computers for teaching math in elementary school allows visualization of mathematical problems, simplifying them for students. Campbell and others point out that the software and hardware should be adapted to the young age of the students and warns against the automatic use of technology at the expense of understanding (Becta ICT Research, 2003).

The math curriculum used by students is a computerized program of study designed to evaluate and drill students in grades 2 through 8. The program presents the student with exercises and word problems suited to the level of knowledge of the material, checks performance and progresses according to the results. It also

provides the teacher with reports on the progress and achievements of each student using the computer (Osin, 1984).

A computer system is intended, among other things, to reveal to the teacher significant heterogeneity among students—even within one class (the levels of students in one class often span two to three years of study)—and encourage teachers to implement math teaching methods tailored to the varying needs of students, not only in the computer room but also in the classroom. Computer drills take place 40 minutes per week. Integrating computers into the teaching is a very important subject to which some of the teachers were introduced during their training (Vrasidas & McIsaac, 2001; Perkins, 1992).

Mevarech and Rich (1985) examined student achievement in math in schools in disadvantaged areas using the Ministry of Education test from 1977. They revealed that the achievements of students in grades 3 to 5 who studied with computer assistance were greater than the achievements of students with similar socioeconomic backgrounds who studied without a computer. Improvements were particularly high among fourth graders who studied with computer assistance: Their achievements were higher than those who were not aided by a computer by a standard deviation of almost 1. Echeverria (1985) found that the rate of progress of groups learning math with a computer was significantly higher than the rate of progress in the control group that did not incorporate computers in the study. Swan, Guerrero & Mitrani (1989) Integration of computers into math study among weak students who are considered underprivileged contributes to improving student achievement at all grade levels, especially those of primary school (Swan, Guerrero, Mitrani, & Schoener, 1990).

Hativa (1988a, 1988b) and Davis, Wiener, Finkelstein and Regev (1986) argue that computer assessment is not reliable since the computer supplies hints that assist the student in solving the problems and enable higher achievement than written tests. Conversely, Osin and Nesher (1989) showed that solving exercises in front of a computer terminal, rather than using paper and pencil, creates difficulty for both advanced and weaker students, alike.

A key aspect of computer-assisted teaching concerns the consequences of it has on classroom teaching methods. One of these studies (Hativa, Shapira, & Navon, 1990) examined a group of teachers who taught computer-assisted math. Teachers reported that computer-assisted teaching exposed them to the diversity among students and encouraged them to find alternatives to the traditional frontal teaching method.

2. Method

The research presented in this paper compares achievement in mathematics in computer-assisted classes, utilizing two teaching methods: alternative or frontal. The study examined student achievement as reported by a computer system, in order to determine to what extent classroom methods for teaching mathematics affect student achievement.

The central variable in the study is the teaching method used in math classes, when computers are integrated in teaching. The main assumption of the study is that teachers who implement alternative teaching methods in the classroom develop their students more than teachers who ignore the diversity among them and continue to teach in the traditional, frontal method.

2.1. Hypotheses

1) Differences will be observed in math achievement between students being taught through frontal teaching and students being taught through alternative methods. Students who learn math through alternative teaching methods will have higher achievement.

2) The math achievement gap will increase with age. The higher the grade, the greater will be the achievement gap.

3) Weak and average students studying in the alternative teaching method will progress more than those studying the frontal method, while high achievers will progress equally in both teaching methods.

2.2. Participants

The participants in the study were 479 students in two urban schools in which students are considered underprivileged by the Board of Education. The students were enrolled in 3 classes each of grades 4, 5 and 6 in each of the schools – 18 classes in all. Also participating were 18 teachers: 9 teachers who teach math using the frontal method of teaching and nine who use the alternative method. Most of the teachers had at least 8 years teaching experience and were graduates of a teachers' seminary or degree programs.

2.3. Instruments

The classes were observed and data concerning time organization, physical environment, educational activity and teaching aids were documented in an observation sheet in order to identify classes with alternative teaching methods. Alternative teaching combines personal instruction, group instruction and classroom teaching while frontal teaching involves presentation and explanation of the material without integrating individual or group work. Observers checked how much of teaching is individual or group, to what extent students have opportunities to work independently, gaining personal experience in the learning process, and to what extent the learning materials are graded and varied. They also evaluated the atmosphere in the classroom, the teacher's work with students and teacher's work with school staff. Observation identified nine classes in which alternative teaching methods are practiced and nine classes in which the teaching method is frontal.

The observation was reinforced with teacher questionnaires containing 59 statements to be ranked from 1—not at all to 5—very much so. The statements referred to openness to change and variety in teaching methods, and the use of

computers in teaching and evaluation. They were critiqued by experts in these fields before completion by the 18 teachers. An analysis of the questionnaire responses confirmed the division into frontal and alternative teaching groups established by the observations and showed the differences in the methods between the two groups to be meaningful and significant. It is important to note that both groups used the computer as an aide for teaching math, but the alternative teachers used it more extensively.

Two years after collection of the research data, we received the average scores of the Ministry of Education's district mathematical achievement tests for the students who were in the 4th grade at the time of collection—three classes from each school. These results may serve as the basis for a longitudinal study, although the tests were done with paper and pencil, not on the computer.

2.4. Process

The teachers in both schools were coached in the same way by the same supervisor, concerning subjects to work on in the computer room and the continuation in the class room. Material regarding teaching attitudes and methods were presented fully to the teaching staff of both schools. The teachers of both schools participated in teacher training conducted by staff of the Ministry of Education in pedagogic centers. One inspector of the Board of Education supervised the activity in both schools. The level required for each class is defined by the teaching plan of the Board of Education.

In both schools, math was taught for 5 hours per week using the same text book, out of which two twenty minute sessions per week (20%) were computer assisted. During the computer sessions, data regarding student achievement was documented by the computer. At the end of each month throughout the school year, the computer reports for all the participants were collected. In addition, observation of one entire lesson was conducted once in each class during the school year, with the authorization of the inspector and coordination with the principal and teacher. The supervisor, who was very familiar with the participating classes and the teachers, supplied supporting information. At the end of the observation, the teacher completed a questionnaire concerning the teaching method used in the class and in the school in general.

We examined three dependent variables of progress: on the computer, solving verbal problems and the number of numerical exercises solved. Progress on the computer and in solving verbal problems is expressed for each by a number arrived at by deducting the student's level at the beginning of the year from the level at the end of the year, with the optimal progress being 10. Progress in the number of numerical exercises solved is expressed as a percentage of the number of exercises solved correctly out of the total number of exercises. The progress is arrived at by deducting the percentage at the beginning of the year from the percentage at the end of the year.

The hypotheses were tested using an analysis of covariance (ANCOVA), with

statistic control of the independent variable, the number of lessons in which the student participated during the school year. We chose this method due to the differences in the number of computer sessions in the classes with different teaching methods. After collecting the data and before analysis, we compared the number of computer sessions held in the alternative method classes and the number in the frontal method classes. The difference was so significant that we classed the data as a controlled variable. In each of the three grades, a great many more computer sessions were held in the alternative method than in the frontal method, as displayed in Table 1.

For the study, the students were grouped into three level groups: weak, mediocre and strong. It was found that the higher the grade, the fewer the students that are up to grade level or above. Notwithstanding, all the classes displayed a strengthening of the level throughout the year. In all of them, the number of weak or mediocre students at the beginning of the year was greater than the number in these levels at the end of the year. Chi-square tests were conducted to examine the differences in annual progress between the three levels of students according to two independent variables: teaching method and age. Differential analyses were not carried out on student levels, due to this variable's dependence on computer scores.

Differential analyses tested the effect of the independent variables—method, age and sex—on the three dependent variables. These analyses were conducted in the groupings: method (2), sex (2) and age (3). Because of the complexity of the analysis, we separated the analysis by method and age from the analysis by method and sex.

3. Results and Discussion

The study examined the average annual progress of the students in math on the computer. The study demonstrates that before installation of computer systems in schools, the average annual progression was 3.5 computer levels per year. This

Table 1. Average participation in computer classes.

Grade	Teaching Method			t	p
	Alternative		Frontal		
4	94.7	M	56.4	17.7	0.000
	(17.1)	SD	(9.40)		
	85	N	100		
5	106.7	M	57.6	28.1	0.000
	(12.4)	SD	(9.1)		
	82	N	70		
6	99.4	M	33.2	18.2	0.000
	(26.7)	SD	(13.7)		
	67	N	75		

index is calculated from the difference between the initial level of evaluation on the computer and the level of achievement as assessed in accordance with the curriculum of the Ministry of Education. It was found that, after installing computers in schools, the weak students progressed at a rate of 5.3 computer levels per year, average students progressed at a rate of 9.5 computer levels per year and high-achievers progressed at a rate of 13.7 computer levels per year. This follow-up study shows that students who studied the math curriculum aided by the computer progressed during the year and high achievers progressed the most.

The level of achievement in math before and after evaluation by computer was also tested among underprivileged populations. The study shows that, before installation of computers in schools, the percentage of success reflected by the computer was 55% but after installation of computers the success rate almost doubled to 93%.

The research indicates satisfaction among teachers, who see great potential in integrating computers in teaching. The reasons for satisfaction include computer management of learning, the detailed reports provided by the computer and its advantages as a means of advancing students. The teachers pointed out the computer reports as a key tool for the individual handling of students and adapting teaching methods to their unique needs.

Teachers also noted the feedback provided by the computer program for each individual student, the diagnostics of student performance and the possibility to identify learning problems, the opportunity for oral practice and the increase in student motivation and expansion of their knowledge. One of the major shortcomings of the system that teachers indicated is that the program does not explain what the student's mistake is.

Most teachers are sure that the computer contributes to the work of teachers and students alike, and express satisfaction from the integration of computers in teaching. The study shows that teachers who integrate computers are usually aware that one must allow students to learn and progress at their own rhythm and challenge them with learning, behavioral and social objectives that are appropriate to their individual ability.

Further evaluation of student achievement in math in that same population after three years of working on the computer, confirms the findings of previous studies (Osin, 1984). It is clear that as far as progress in math in underprivileged populations is concerned, the effectiveness of the computer system is retained even after the novelty wears off and the system is no longer foreign to students.

3.1. Hypothesis I

Comparison of the observed averages with the corrected averages if all the students had participated in the same number of computer sessions showed significant differences in progress in solving exercises between the two methods ($f(1,459) = 5.33$, $p = 0.02$). Students who were taught in the frontal method ex-

perienced a decrease in the number of exercises solved correctly (m = −5.17), while students who were taught in the alternative method achieved an increase in the number of exercises solved correctly (m = 3.15). The differences in the computer were not significant at a level of 0.05, but were significant at $p = 0.08$ in favor of the alternative method (f(1,459) = 2.94, $p = 0.08$). No difference was found in solving verbal problems.

3.2. Hypothesis II

The differential analysis compared the three dependent variables under the effects of the independent variables—class level and teaching method—with the number of computer sessions as a controlled variable. This analysis showed a significant interactive effect in progress on the computer only (f(2,459) = 16.7, $p = 0.000$) and not in the other two variables. A post-hoc test to check the interactive effect showed a significant effect in all class combinations. F values for the differences between grades 5 and 6 were extremely high, and even more so between grades 4 and 6, indicating that the gap widens with age, favoring students of the alternative method. This corroborates the second hypothesis: the older the student, the greater his improvement. **Figure 1** illustrates how the difference in achievement in math between students who were taught with the different methods widens from 4th grade to 6th grade.

A comparison of the observed averages with the corrected averages—those we would have expected if all the students had participated in the same number of computer sessions—shows that in the frontal method the progress was expected to be higher than it actually was, while in the alternative method the progress was expected to be lower than it actually was. **Figure 1** illustrates the significant progress—beyond that expected—of students who were taught with the alternative teaching method and the slower than expected progress of students who were taught with the frontal teaching method (Stevens, 1986).

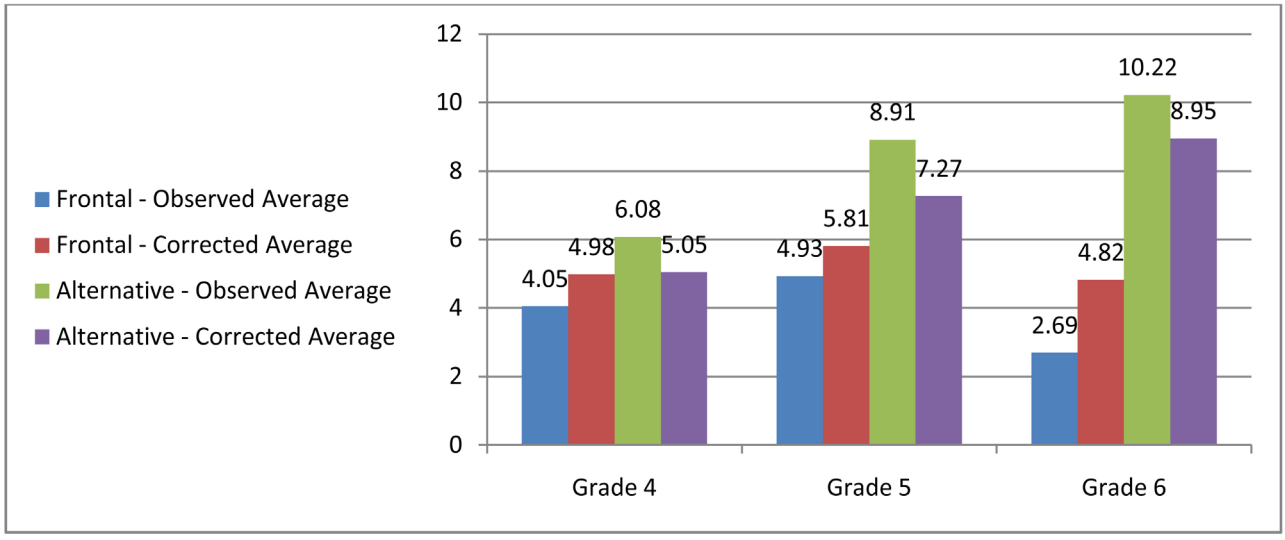

Figure 1. Average progress according to method and grade.

3.3. Hypothesis III

To test this hypothesis, students in each class were categorized in three groups, according to their computer level compared to the rest of the class. Their progress is classified into five groups:

- Weak students at the beginning of the year who remained weak at the end of the year (W-W).
- Weak students at the beginning of the year who progressed to mediocre at the end of the year (W-M).
- Mediocre students at the beginning of the year who remained mediocre at the end of the year (M-M).
- Mediocre students at the beginning of the year who progressed to strong at the end of the year (M-S).
- Students who remained strong from beginning to end (S-S).

Only one student who began the year in the strong group regressed to mediocre at the end of the year. For the study, this student was included in the S-S group. Similarly, only two students who began the year in the weak group progressed to the strong group at the end of the year. These students were included in the W-M group. Not a single student who began the year in the mediocre group regressed to weak at the end of the year. Most of the students maintained their level or progressed to a higher level.

The third hypothesis was checked with a chi-square test, using as variables the five categories described above in frontal teaching and in alternative teaching. The analysis showed that 29% of students in the frontal teaching method began weak and remained weak. By contrast, not one of the students in the alternative method who began the year weak (approximately 5%) remained weak at the end of the year. Similarly, a large number of mediocre students in the alternative method progressed to strong at the end of the year (35.2%), while in the frontal method only 18% progressed similarly. Especially striking is the large percentage of strong students in the alternative method who maintained their strong standing (49.3%), compared to the relatively low number in frontal teaching who performed similarly (20.4%).

Analysis of the distribution within the groups showed that in the alternative method most of the students who began the year as mediocre progressed to strong standing (76.9%), while in the frontal method most mediocre students remained mediocre (53.7%). Note that strong students at the beginning of the year maintained their strong standing, regardless of the method of teaching.

In conclusion, the most striking finding is that most of the students in the frontal method remained in their original level, while most students in the alternative method progressed to a higher level. This corroborates the third hypothesis.

4. Ministry of Education Test Scores

The average test scores for the two types of classes show that even in the district test conducted two years later, the students in the alternative method retained their lead on those from the frontal method. The average scores of 6th graders

who had been in 4th grade frontal method classes (61.7, 61.8, 62.5) were substantially lower than the scores of those who had studied in the alternative method (68, 77.4, 84.3).

In addition, the percentage of failures in the district test was compared with the percentage of failures collated from the computer results two years earlier, for each of the teaching methods. Of the students of the frontal method, 32% failed in the computer and 39% failed the district test, while only 14% of alternative students failed in the computer and 16% failed the district test. These results of the district test echo the computer results of two years earlier, even though different instruments were used.

5. Summary of Results

The findings indicate that the teaching method that combines computer-assisted learning and alternative classroom teaching methods has a significant effect on student achievement in mathematics. These students display higher achievement than their peers who learn in the frontal method. This effect on achievement was preserved even when the number of computer classes in which the student participated during the school year served as a controlled variable. Significant differences were found between the two teaching methods regarding progress in the computer and progress in solving exercises.

Furthermore, interaction between teaching method and age was found: We found that the older the students, the greater the gap in achievement on the computer, in favor students of the alternative teaching method. The gap in achievement between students who studied in the method that combines computer-assisted learning and alternative classroom teaching methods and their peers who did not was sustained for two years, as shown by the results of the written district test of the Ministry of Education. The percentage of success in the district test was significantly higher among students who studied in the method that combines computer-assisted learning and alternative classroom teaching methods (84%) than among those who did not (61%).

6. Discussion

The hypothesis that there is a connection between the teaching method used in the classes and student performance in mathematics is based on the findings and conclusions of Salomon, Almog and Ben Zakan (1993), Solomon, G. (1994), Solomon & Gardner (1986), Safir, Hertz-Lazarowitz, Ben Tsvi-Mayer & Kupermintz (1992), who all claim that one must diversify the teaching methods, undermine the domination of the traditional frontal teaching method, activate and involve students in their learning and introduce teaching technologies tailored to the needs and different levels of students in the heterogeneous class. According to Goodlad (1974), all learning is individual learning and there may be no other kind (Lazarowitz, Hertz-Lazarowitz & Baird, 1994).

The findings show that students learning with alternative teaching methods

attain higher achievement than students learning with the frontal teaching method, both on the computer in all the categories and solving exercises.

It should be noted that in all cases, the number of computer classes attended by each student was taken into account. This variable was statistically controlled in the covariance analysis. Advance comparisons showed that, on the average, students in the frontal teaching method attended about half the number of computer classes attended by those in the alternative method. In any case, the findings show a gap in achievement favoring the students who studied with the alternative teaching method, regardless of the number of computer classes in which the students participated.

The study also investigated whether the teaching method has a different effect on different age groups from grades 4 to 6, i.e., if the gap in achievement increases with age. The findings show that the gap between students in the alternative method and students in the frontal method increases as the students get older. It appears that students studying in the alternative method improve their level over the years, while students studying in the frontal method weaken over the years.

The study also examined the progress of students according to their level within the class (weak, advanced) and the method of teaching in which they learn. It was found that a significant percentage of students who studied in the alternative teaching method progressed to a higher level within their class (from the weakest group to average, and from average to advanced) or retained their high achievement level. In contrast, most of the students who studied in the frontal method remained at the level in which they began the academic year: weak students remained weak, average students remained average and advanced students remained most advanced. In other words, weak and average students in the alternative teaching method are able to reduce the initial gap between them and their classmates, while students in the frontal method fail to close the achievement gap and are left behind.

The findings of the district tests of the Ministry of Education support these findings. A comparison of three classes that studied in the alternative method of instruction with three classes in the frontal method shows that the gap in achievement which the computer reported to teachers is also reflected in the results of the district tests held two years later.

6.1. Teachers' Work in the Different Methods

The basic conditions for teaching mathematics were similar in the two schools, yet the basic approach concerning the teaching method in the classroom differed. In spite of the similar conditions, the achievement level in the alternative method was higher. This raises the question: What takes place in the classroom, and how does it affects the differences in achievement between the classes that follow different teaching methods.

One may discuss this phenomenon on two levels:

1) Classroom teaching.

2) The connection between classroom teaching and learning in the computer room.

In classes which practice the alternative method of teaching, teachers relate to differences between the students and match the teaching method and study material to the unique needs and personal capabilities of each student. In this method, the teacher does not settle for the role of instructor, but passes responsibility to the student. In this way, each student is given a chance to learn and progress at their own pace and make the most of the learning process. Conversely, when the frontal teaching method is used, the teacher addresses the whole class and teaches according to the curriculum, without any regard to the variation among them. This teaching method is not suitable for students with unique needs: Advanced students do not find interest in the material and waste their time in the classroom, while the weak are not able to follow the subject matter and do not, in fact, participate in the learning process.

We may conclude that students in the alternative teaching method benefit from the learning process and each one advances according to his ability. Frontal teaching method, however, is effective only for average students and does not contribute to the advancement of the weakest and most advanced students in the class. As a result, there is a widening of the achievement gaps between those in frontal teaching and those in the alternative method.

The different teaching methods in the classrooms also affect students in the computer room. Computer-assisted learning is individual learning, in which each student advances according to his personal ability and level. The alternative method of teaching suits the work in the computer room, continues and completes it. Similarly the learning process in the computer room affects the classroom learning. Difficulties that arise in the computer room are resolved by the teacher in the classroom and vice versa, difficulties that arise in a classroom are resolved in the computer room. This ensures the continuity of the learning process between the classroom and the computer room and its effectiveness increases.

By contrast, frontal teaching is disconnected from the learning process in the computer room. Difficulties that arise during the work in the computer room are not resolved in the classroom where the teacher teaches the entire class a central subject corresponding to the average level of the students there. A student experiencing difficulties with the material is unable neither to keep up in the classroom nor to progress in the computer room, so his loss is double. The teacher that sticks to the frontal teaching method ignores the diversity among students that is revealed in the computer room and continues to teach class according to the average level, which does not necessarily reflect the actual level of different students in the classroom. For example, an advanced student exhibiting a high level of achievement in the computer room will be forced to revise already familiar material in the classroom.

Teachers working with the alternative teaching method consider computer

learning an integral part of their work. By contrast, teachers of the frontal method do not attach importance to the computer's impact on the learning process in the classroom and its potential as a tool to promote student achievement. Moreover, this method of work is foreign to them, so they do not succeed in creating continuity with the differential process started in the computer room.

In conclusion, though the work in the computer room exposes the teacher to student diversity and encourages differentiated work, teachers in the frontal method do not exploit the possibilities offered by the computer. In contrast, teachers using the alternative method create an amalgamation of instruction that combines classroom teaching and the learning process in the computer room, thus allowing students to progress and achieve higher results in math. In this context, it is worth noting that, over time, a school develops a teaching and learning culture that draws on its prevailing educational approaches and becomes integrated into its ethos. This can explain the difference between the schools that occurs despite the equal conditions in the learning environment.

The school with the alternative teaching method was prepared to exploit the variety of available options and tools—guidance, training, appropriate textbooks and various teaching aids—and used these tools to develop teaching methods tailored to the needs and ability of the student that allow him to improve in math. Conversely, the school where the frontal teaching method was practiced was not yet ready to accept the assistance offered and failed to use the available tools to improve teaching methods and advance the students.

6.2. Differences in Student Achievement in the Different Methods

The processes that students are exposed to in each of the teaching methods are what underlie the disparity in achievements. In the alternative method, the student is the heart of the learning process, takes responsibility for it and is actively involved in it. Students of the alternative method receive assistance and appropriate response to the difficulties they encounter in the computer room, and continue to deal with the issues that present problems for them in the homeroom, at a level consistent with their personal ability. When these students return to the computer room, they are in control of the material and can continue to move forward on the basis of the knowledge gained. Students in the frontal method do not receive adequate assistance and or response to the problems they encounter. The learning process that occurs in the computer room has no continuation in the classroom. In the absence of support and reinforcement, the process stops and the progress of these students are halted.

The findings corroborate the findings of Hativa (1986, 1988), according to which computer-assisted learning contributes to an increase in the gap between weak and advanced students and promotes good students in disadvantaged schools. It seems that good students do not need much help from the teacher; their natural curiosity and knowledge gained contribute to their progress, regardless of the method in which they learn. Weak students, however, need per-

sonalized, focused assistance from the teacher. They do not receive this assistance in the frontal teaching method, so their progress is halted. In the alternative method, students receive personalized assistance and progress according to their own pace and ability.

The study found gaps in the achievement of students studying in the various teaching methods in all the progress indices, except the index of verbal questions. The findings indicate that in all other variables, students studying in the alternative method attain higher achievement than students studying in the frontal method, while in the verbal questions there is no difference in the achievements of the two groups. A possible explanation lies in the structure of the computer-assisted math curriculum. The computer presents a fixed number of verbal problems with a defined hierarchy. Questions in a particular topic are based on a fixed text with numbers that change from question to question. Progress is contingent on correctly solving the earlier questions in the sequence. The questions are ranked sequentially from second grade to eighth grade.

During the computer practice, students are introduced to ten problems. The student must correctly solve at least six questions on the first try in order to move to a higher level. If the student does not succeed, the computer displays questions of similar structure with different numbers. In the second round, the requirements diminish and the threshold for success is lower, but in any case, the student must cope with ten verbal problems with the required level of success in order to advance to a higher practice level. In the other areas, the computer presents no more than five to ten exercises, although here, also, the student must achieve the required level of success in order to advance to a higher level. In other words, to advance in level in verbal problems, students must participate in a greater number of classes than required in order to advance in other areas. Thus, the effect of the number of computer classes in which the student participated on the progress in verbal problems is clear.

In this connection, one should note that the method for verbal problems in the computer-assisted math curriculum has not yet been finalized because of the complexity involved in ranking verbal problems according to levels of difficulty, which requires evaluation of the content regarding incorporated semantic, linguistic, logical, mathematical and other elements.

7. Conclusion

The study examined the achievement of students in grades 4 to 6 in mathematics as displayed by a computer system, in classrooms where alternative teaching methods are used and classes with frontal teaching methods.

The achievement was measured in terms of progress in the computer, progress in solving problems, and progress in solving exercises.

The findings indicate higher achievement among students who studied in the alternative teaching method at any age. In addition, the gap was found to widen as students grew older, as the extent of mathematical knowledge required by the

student expands and gaps in knowledge grow from year to year, in the absence of an appropriate response to the difficulties the student the part of the teacher. The study shows that the alternative method promotes improvement in weaker and mediocre students, while the frontal method does not. Weak students studying this method remain weak and average students remain average. Only the strong students maintain their high results in both types of teaching (Salomon, Almog, & Ben Zakan, 1993). This is explained by the fact that alternative teaching maintains continuity between the classroom learning process and learning activity in the computer room. In frontal teaching, conversely, there is a lack of connection between the classroom learning and the computer classroom.

Students who learn in a method adapted to their needs and ability gradually acquire the level of knowledge required for their age, and progress linearly over time. Students who learn in the frontal method not only do not maintain their level, but drop in level over the years compared to students in the alternative teaching method.

The results of the Ministry of Education district tests also display gaps in student achievement between the different teaching methods—gaps retained over the years. Students in alternative teaching attained relatively high achievement in the Ministry of Education district tests held two years after the study data collection, compared to students learning in the frontal method. This finding supports the hypothesis and sheds new light on the earlier findings of Mevarech and Rich (1985) that showed a gap in achievement between students in computer-assisted study and students studying without computer assistance. It turns out that such a gap also exists when students are all taught with the assistance of a computer but are exposed to different teaching methods in their classrooms.

Both our study and other studies show that the teaching method used has far-reaching impact on student achievement. It was found that the alternative teaching method is the effective method that advances the student when utilized wisely in the learning process.

8. Recommendations

It should be noted that the computer that served us for the purpose of collecting and analyzing data, is only a model.

The findings indicate the necessity and importance of integrating classroom teaching process and the learning process in the computer room. This requires flexible orientation and coordination between that taught in the classroom and computer room activities. Integration of computers in teaching is not much value in the absence of qualitative changes in teaching and learning processes. Technical adaptation alone will not justify the effort spent on installing a computer system in the school without the necessary qualitative changes, i.e., adaptation of teaching methods and the underlying educational approach to the new reality in schools.

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