

# How Teaching Method (Alternative/Frontal) Affects Achievement in Mathematics for Boys and Girls in Grades Four to Six Who Are Learning in a Computer-Assisted Environment

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## Abstract

A comparison of teaching methods in mathematics (frontal vs. computer enhanced and/or other alternative methods) in two urban elementary schools (479 students; grades 4 - 6; total 18 teachers) indicated that a significant difference in the achievement of the students resulted from the latter method, particularly for girls in the case of answering word problems. Follow-up studies corroborated the findings, indicating that the teaching method is a decisive factor in student achievement in math and that enhancing teaching with computer practice is of prime importance. This study's basic assumption is that there will be a correlation between the teaching method (alternative or frontal) in the mathematics class in primary schools were mathematics learning is computer assisted and the pupils' achievements in mathematics. This led to study the relationship between pupils' progress in various types of mathematical word problems, and the teaching method by which they were taught, and in correlation to the factors of pupils' age (grades 4 - 6), gender, and initial level of mathematical knowledge (poor, average, advanced). The results showed that the alternative teaching method clearly led to higher achievements overall but especially so for word problems in the case of girl, which in fact demonstrated the highest progress of all the factors studied. The results were corroborated in the region-wide government-administered tests given two years after the initial data collection. The study thus shows that the teaching method used in the mathematics classroom is a central and extremely influential factor in pupils' progress in mathematics and shows the importance of fully coordinating the teaching in the classroom with the mathematical activities on the computer. The results point to an urgent need to fully coordinate classroom instruction with the computer activities, some-

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thing that is vital in any situation where learning is amended with computer work.

### **Keywords**

(3-5) Achievement in Mathematics, Boys and Girls (Gender), Teaching Method—Alternative and Frontal, Learning in a Computer-Assisted Environment, Elementary School

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## **1. Introduction**

Less than 60% of students in Israel achieve a passing mark in math in elementary school, and only a small percentage of high school students graduate with a proper understanding of science and math, despite recent technological developments in education (Harari, 1992). This aligns with international data that shows a decline in math and science studies, especially in remote and underprivileged neighborhoods (Harari, 1992). Children in underprivileged areas do not normally have access to appropriate (or state-of-the-art) educational resources, and teachers who teach in underprivileged areas often do not have proper training (Reznitskaya & Gregory, 2013). The lacuna of such children, who lack school preparation and are deficient in perception, speech, sorting, abstraction, reading, and conceptual abilities, gradually increases with time, often resulting in failure to graduate.

The computer is highly regarded for its contribution to improving learning capacity, strengthening student confidence, and preparing them for the modern world (Salomon, 2002; Salomon & Perkins, 2005). The gap between the underprivileged and the well-off is clearly denoted by the prevalence of computers in the learning environment. The former is much less likely to access computer-assisted learning: in fact, about 32% of students in affluent schools participate in computer-assisted learning compared to only 17% of underprivileged students (Sutton, 1991).

### **1.1. SRRE: Student Populations That Require Remedial Learning Opportunities for Learning Mathematics**

The population of students examined in this study is, for the most part, students who require remedial education (SRRE). According to a UNESCO report (1968), SRREs are children and adolescents who, for social reasons, may be unable to reach the levels of achievements which they should be able to reach under normal conditions; oftentimes, they do not even reach the average achievement level in their own country. Generally speaking, SRREs do not have access to suitable educational institutions and in many cases, when they do attend an institution, are unable to take full advantage of it. These are children and youth who have difficulty understanding and assimilating the educational values and who reject any attempts made by teachers to get close to them despite the teachers' goodwill

and willingness to help. They demonstrate inhibition in social settings, and this is reflected by poor verbal skills and unwillingness to try new experiences. If this were not enough, members of this group seem to lack all sense of time. Taken all together, these factors inhibit their progress in school.

As the children grow up, these setbacks come to the fore in the absence of work habits, inability to follow routines in the long-term, and preference for trivial, immediate satisfaction over greater yet deferred gratification. All these have a negative effect on their motivation to succeed in school. Educationally speaking, members of this group characteristically are lacking preparation for school, lack skills in understanding, speech, the ability to group/sort/classify, abstraction, reading ability, and designing concepts.

SRRE children come to school deficient in the basic skills required for learning and, over time, this deficiency accrues. Combined with their low motivation and self-confidence and their averseness to their teachers and school, predicting their fate is not difficult: these children grow up without acquiring the most basic of information, will not be able to overcome obstacles, will lose all hope concerning their opportunities to develop and advance, so that the gap between them and their peers who started out from a more preferred position becomes overwhelming. Often, this process culminates with the SRRE dropping out of the educational system, thus perpetuating their inferior situation beyond the framework of school—that is to say with respect to employment, in particular, and to life, in general.

In Israel over the last decade, the increase in the gap between social strata, on the one hand, and the reduction of resources available to the Ministry of Education and Culture, on the other, have exacerbated the situation in the educational system, leading to an ever widening the gap between educational opportunities. Furthermore, the efforts of parents in higher socio-economic layers to broaden and enrich their children's education, both with respect to core subjects and other interests (in after-school classes organized by private entities) and the Ministry of Education (MoE) inability to offer such enrichment to pupils from the lower socio-economic layers (typically defined as SRRE) has intensified the gap between outstanding and underachieving student seven more, and reducing the ability of vulnerable populations to progress, develop, and cope with the modern world.

The above-mentioned gap in opportunities between SRREs and the more established student strata of students is profoundly manifested in the field of computers. In fact, it has been found that SRREs have much less chance of experiencing computer-assisted learning than their more established peers. Sutton (1991) reported that an estimated 32% of students in schools of high socio-economic level experienced computer-assisted learning compared to only about 17% of SRREs.

## 1.2. Alternative Teaching Methods

The use of alternative teaching methods stems from the attitude that diverse

teaching methods can activate and engage students. Integrating technologies adapted to the different needs and levels of the heterogeneous classroom helps address psychological and epistemological aspects, serves as a basis for creating models for mathematics teaching, and takes into account the abilities and limitations of each child. Alternative teaching methods include encouraging discussion and dialogue by asking a leading question and echoing students' ideas. Another method is teaching in small groups, which allows more effective learning and flexible instruction based on the unique needs of the individuals in the group and one other alternative teaching method is the use of the computer (Thorvaldsen, Vavik, & Salomon, 2012).

Harari has shown that incorporating computers in teaching contributes 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" (Harari, 1992: p. 7). Osin, Neshet, and Ram have noted that "teaching mathematics in elementary schools using computers improves student achievement" (Osin, Neshet, & Ram, 1994: p. 15). Computers can enhance the teaching of math in elementary school by allowing visualization of mathematical problems, thus simplifying their comprehension.

In Israel, the math curriculum (grades 2 through 8) comprises a computerized program of study designed to evaluate and drill students. It presents exercises and word problems suited to the grade (or knowledge) level, checks performance, and progresses according to the results. The computer system provides the teacher with reports on progress and achievements for each student (Osin, 1984; Osin & Neshet, 1989), thus revealing heterogeneity among students, even within one class (the levels of students in one class often span two to three years of study) and encouraging teachers to implement teaching methods tailored to the varying needs of students, not only in the computer room but also in the classroom. One group of mathematics teachers reported that computer-assisted teaching alerted them to the diversity among their students, which encouraged them to find alternatives to the traditional frontal teaching method (Hativa, Shapira, & Navon, 1990).

Mevarech and Kramarski (1997) examined student achievement in math in schools in disadvantaged areas and found that students in grades 3 to 5 with similar socioeconomic backgrounds achieved more when they studied with computer assistance. Improvements were particularly high among fourth-graders who studied with computer assistance: their improvement showed a standard deviation of almost 1. Other studies (Swan, Guerrero, Mitrani, & Schoener, 1990) demonstrated similar results.

### **1.3. The Value of Integrating Computer Systems**

Regarding the average annual progress of the students in math on the computer, a study carried out by the MoE demonstrated that before introduction of computer systems in schools, the average annual progression was 3.5 computer levels per year (calculated as the difference between initial and final levels on the

computer, assessed in accordance with the curriculum of the MoE). After the computers' introduction, the rates of progression (over the academic year) for weak, average, and strong students were 5.3, 9.5, and 13.7, respectively. In short, all students whose mathematics studies were aided by the computer progressed significantly during the year, but high achievers progressed the most (Harari, 1992).

Similarly, mathematics achievement levels before and after introduction of computers were tested among underprivileged populations. The study shows that improvement, as reflected by the computer, was almost double: 55% to 93% (Harari, 1992).

Studies also reported satisfaction among teachers, who see great potential in integrating computers into teaching, not the least of which is computer management of learning and the detailed reports a computer can provide, which lead to the means of advancing students. Teachers noted that feedback provided by computer reports was a key tool for handling students on an individual basis and adapting teaching methods to their students' unique needs. Furthermore, the diagnostics of student performance allowed identification of learning problems, the opportunity for oral practice, and the increase in student motivation ultimately leading to the expansion of knowledge. One of the major shortcomings of the system that teachers indicated was that the program does not explain what the student's mistake is.

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

Further evaluation of student achievement in mathematics in that same population after three years of working on the computer confirmed the findings of previous studies (Osin, Neshet, & Ram, 1994). 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.

#### **1.4. Comparing How Male and Female Students Use the Computer in School**

This current study also aimed to investigate if student gender was a factor that affected their experience in computer-assisted learning. Previous studies have examined correlation between student gender and achievement in computer-assisted learning in the case of struggling students and indicated that boys benefit far more when learning with the computer (Tiedemann, 2000). It was also found that boys have greater confidence than girls in their ability to achieve in the fields of computers and mathematics, even when there is no difference

between the two genders in early computer experience. Other research has suggested that girls have more negative attitudes than boys about using a computer and, already in elementary school, computers are perceived as a “male domain.” Boys use the computer more than girls and reveal more positive attitudes about the use of the computer. It was also found that boys participate more in computer-related activities by choice, demonstrate more interest in the subject both at home and at school, tend to read information devoted to this domain, and reveal a greater degree of knowledge and adeptness in the subject of computers. This gap in knowledge between the two genders can be explained by boys’ greater experience in communicating with the computer (Sutton, 1991). Interviews conducted with students on this topic reveal that girls tended to address the computer workspace whereas boys focused on the technology and techniques related to the computer. This difference in attitude can be explained by the boys’ self-awareness of mastering the computer and also, as said, by the greater experience they have accumulated in this field (Sefer, Hertz-Lazarowitz, & Ben-Tzvi-Meir, 1993; Ben Tsvi-Mayer, Hertz-Lazarowitz, & Safir, 1993; Preckel, Goetz, Pekrun, & Kleine, 2008; Birenbaum & Nasser, 2006; Goetz, Bieg, Ludtke, Pekrun, & Hall, 2013; Else-Quest, Hyde, & Linn, 2010). It is worthy to note in this context that in schools where computer lessons are an integral part of the curriculum—especially in primary school—there was no difference found between the genders in the tendency to take part in activities that were computer related, in their positions regarding using the computer, or any anxieties related to it.

It is worthwhile noting, however, that Mores and Daiute (1992) have claimed that, apparently, the investigators themselves were a cause of the bias against women and girls in the studies that involved the subject of computers and how the different genders use them. They point out that different methodological elements in studies that deal with gender and computer use and/or gender-correlated functionality in this area are biased from the outset, and this bias perpetuates the gender gap with respect to computers. To prove their claim, Mores and Daiute observed over a number of weeks the behavior of both genders in the computer environment. They found that the female attitude with respect to the computer was extremely positive: they were excited to use the computer and exhibited much confidence using it. In parallel, the researchers carried out a study about attitudes using a questionnaire and found that the attitudes of the female students, as reflected in the questionnaires were significantly different from the results obtained through observation.

## 2. Method

### 2.1. Hypotheses

Our main assumption is that students who are taught with alternative teaching methods in the classroom develop more than those who are taught in the traditional, frontal method, where teachers tend to ignore student diversity. We thus

compare student achievement in mathematics in computer-assisted classes. Half the study population was taught by the frontal method and half by alternative methods (small groups, more discussion, etc.). Student achievement data was supplied via the report of the school's computer system.

We developed four hypotheses:

1) Weak and average students taught by alternative methods will show higher achievement than those taught by the frontal method.

2) The gap between methods will increase with age.

3) High achievers will progress equally in both teaching methods.

4) Significant differences will be found in achievement in mathematics between male and female students who are taught by the different teaching methods, since girls will better express their ability in small groups and will tend to participate more actively in activities presented in this framework in which their chance to develop their mathematical thinking is greater.

The central variable in the study is the teaching method (frontal or alternative) used. Note that both groups used the computer as an aid for teaching math, but the "alternative" teachers used it more extensively.

## 2.2. Participants and Definitions

The research population ( $n = 479$ ) included both male and female students studying in two urban schools considered "underprivileged" by the Board of Education: three classes each of grades 4, 5, and 6 in each of the schools (total: 18 classes and 18 teachers, see **Table 1**). Most of the teachers had at least eight years of teaching experience and were graduates of a teachers' seminary or degree programs. Nine teachers taught math using the frontal method and nine used the alternative method.

"Frontal instruction" is teaching in which the teacher faces the class as a whole and where the material is taught using presentations and explanations and without any individual or group work. "Alternative instruction" is defined as instruction that combines personalized, group, and class-wide instruction. For the purpose of this study, the classes were divided equally between those in which alternative teaching and frontal teaching was generally used.

**Table 1.** Population, male and female students and teaching method.

Teaching Method	Teaching Method				Total
	Frontal		Alternative		
Gender	F	M	F	M	
Grade 4	52	48	44	41	185
Grade 5	34	36	36	46	152
Grade 6	38	37	33	34	142
N	124	121	113	121	479

### 2.3. Instruction Protocol

The level of mathematics instruction required for each class was defined by the teaching plan of the MoE. Identical textbooks were used in both schools. Math was taught for an identical amount of time (five hours) per week: two 20-minute sessions were computer-assisted and student achievement data was documented by the computer.

All the teachers underwent identical coaching by the same supervisor concerning subjects to work on in the computer room and in class, were presented with comprehensive information regarding teaching attitudes and methods, and participated in teacher training conducted by MoE staff. One MoE inspector supervised all the activity and supplied supporting information.

### 2.4. Data Collection

The study combines quantitative and qualitative research methods. Quantitative data were gathered using a questionnaire completed by the teachers to verify their attitudes with respect to changing teaching methods at the school, the teaching methods they usually use, and the use of alternative tools and the integration of the computer in the school. Quantitative data were also obtained from computer reports when students used it as part of their learning experience. Qualitative data included observations of the classroom and computer room and interviews held with the teachers. The teaching method used in the classroom was ascertained through the observations and interviews.

**Observation.** Qualitative data concerning time organization, physical environment, educational activity, and teaching aids were documented on an observation sheet to identify those classes where alternative teaching was employed. (Frontal teaching was defined as presentation and explanation of material without integrating individual or group work.) Observers checked how much of classroom time was devoted to individual or group teaching, to what extent students had opportunities to work independently and gain personal experience in the learning process, and to what extent learning materials were graded and varied. They also evaluated the atmosphere in the classroom and how the teacher worked with students and staff.

**Questionnaires.** The observed data was reinforced by the teacher questionnaires, which comprised 59 Likert-type statements [ranked from 1 (not at all) to 5] that addressed teachers' openness to change and variation in teaching methods, and the use of computers in teaching and evaluation. Questionnaires were critiqued by experts before distribution. Analysis confirmed the division into frontal and alternative teaching groups established by observation, and showed the differences between the two methods to be meaningful and significant.

### 2.5. Data Analysis

Hypotheses were tested using 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 according to the teaching methods. After collecting data and before analysis, we compared the number of computer sessions held in the two types of classes. The differences were so significant [Grade 4: 94.7/56.4 hours (alternative/frontal); Grade 5: 106.7/57.6; Grade 6: 99.4/33.2] that we classed this data as a controlled variable. **Table 2** presents the average number of computer classes given to grades 4, 5, and 6, as a function of teaching method (alternative or frontal).

As can be seen in **Table 2**, in all grade levels, students taught with the alternative method also had a much higher number of computer classes. Nevertheless, the number of mathematics classes held was the same for each: five hours per week, in accordance with MoE guidelines.

As noted, based on our observations, teachers were divided into those who used the frontal method and those who used the alternative method. Analysis of the teachers' responses to the questionnaire clearly suggests significant differences between the two groups and underscores and reinforces the observed differences **Table 3** summarizes the findings from the questionnaire.

From **Table 3** one can observe that there is a significant difference between the opinions of the two groups of teachers with respect to teaching methods.

**Table 2.** Student participation in computer classes as a function of teaching method.

		Teaching Method		t	p
		Frontal	Alternative		
Grade 4	X	56.4	94.7	17.7	0.000
	SD	(9.4)	(17.1)		
Grade 5	X	57.6	106.7	28.1	0.000
	SD	(9.1)	(12.4)		
Grade 6	X	33.2	99.4	18.2	0.000
	SD	(13.7)	(26.7)		

X = Average number of computer classes; SD = Standard deviation.

**Table 3.** Characterization of instruction methods.

		Teachers Positions		t	P
		Frontal (N = 9)	Alternative (N = 9)		
<b>Different teaching methods in the school</b>	X	2.34	3.36	5.64	0.000
	SD	(0.38)	(0.38)		
<b>Teaching methods and use of teaching tools</b>	X	2.36	3.18	5.85	0.000
	SD	(0.21)	(0.36)		
<b>Use of computers in the school</b>	X	3.16	3.74	3.93	0.000
	SD	(0.26)	(0.35)		

X = Average number of teachers who answered yes to the items in the specified field; SD = Standard deviation.

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

Students were divided into weak, average, and strong groups. Chi-square tests were conducted to test differences in annual progress between these three levels with respect to the two independent variables of teaching method and age. Differential analyses were not carried out on student levels due to this variable's dependence on computer scores.

Two years later, we obtained the average scores of the MoE's regional 6th-grade mathematical achievement tests for the students who had been in 4th grade at the time of our study (three classes from each school) to further analyze the effectiveness of the teaching methods.

### 3. Results

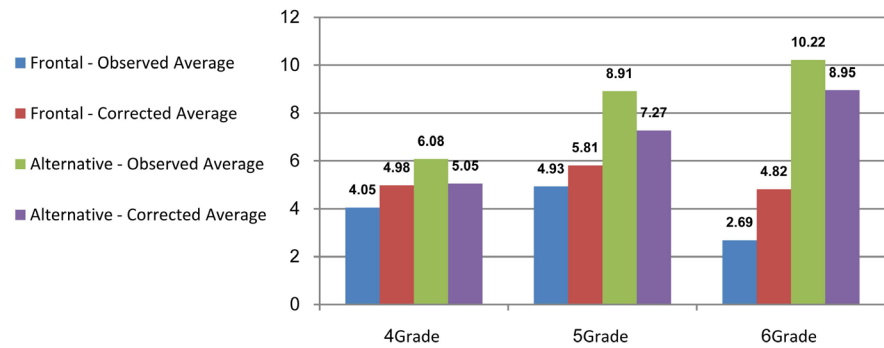
We found that as the grade level rose, fewer students met grade level criteria (or above). Notwithstanding, all classes displayed a strengthening of level throughout the year, that is, there were fewer weak or average students at the end of the year than the number at the beginning.

Regarding our four hypotheses, we concluded the following:

**Hypothesis I.** Comparison of observed averages with corrected averages (had all the students participated in the same number of computer sessions) showed significant differences in progress in solving exercises ( $f(1,459) = 5.33, p = 0.02$ ). In fact, students who were taught in the frontal method demonstrated a decrease ( $m = -5.17$ ) but alternative-method students showed an increase ( $m = 3.15$ ). The differences with the computer were not significant at a level of  $p = 0.05$ , 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 word problems.

**Hypothesis II.** Differential analysis was used to compare the three dependent variables under the effects of class level and teaching method (the number of computer sessions was a controlled variable). This showed a significant interactive effect in progress for the computer only ( $f(2,459) = 16.7, p = 0.000$ ) but not for the other two variables. A post hoc test to check interactive effect was significant 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 the alternative method. This corroborates our second hypothesis: the older the student, the greater his/her improvement. **Figure 1** illustrates how the gap in achievement widens from 4th grade to 6th grade for both methods.

**Hypothesis III.** Students in each class were categorized into a total of five groups based on their relative computer levels at the beginning and end of the year as follows: initially weak and remaining weak (W-W), initially weak and progressing to average (W-M), initially average and remaining average (M-M),



**Figure 1.** Average progress according to method and grade.

initially average and progressing to strong (M-S), strong students (all remained so throughout the year) (S-S).

(Note: For the purpose of this study, one student who began strong but regressed to average is included in S-S; two students who began weakly and progressed to strong are considered W-M.)

We checked this hypothesis with a chi-square test using the five categories described above as variables (for frontal and alternative teaching). With the frontal method, 29% of the weak students began and ended the year (frontal teaching) as weak (*i.e.* 71% progressed). 18% of the average students progressed to strong (*i.e.* 82% remained average), and only 20.4% of strong maintained their standing.

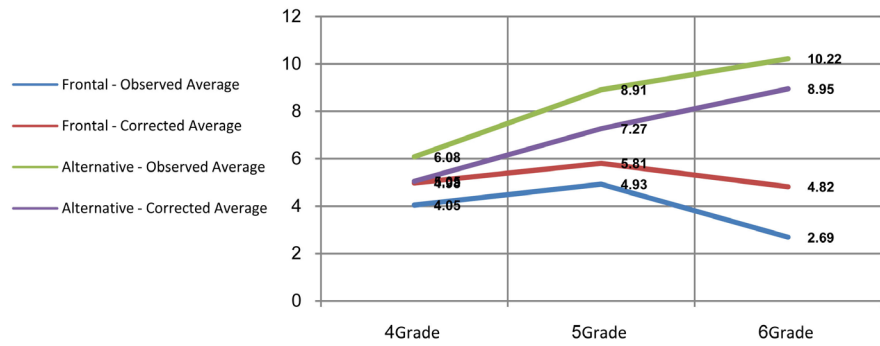
By contrast, in the alternative classes, not one of the 5% who began weakly remained so by the end of the year. Similarly, 35.2% of the average students progressed to strong, and 49.3% of students who began as strong maintained their strong standing

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

With respect to hypothesis 2, that is, that the gap in mathematical achievement between the two groups of students (based on teaching method) would increase with the grade level, **Figure 2** shows that the gap in achievement does, indeed, increase with an advantage to the alternative teaching method. This expected differential progress can be explained by the fact that gaps not attended to end up expanding with time.

**Table 4** displays the results of the covariance analysis, where grade level (4, 5, 6) and teaching method (alternative, frontal) is the uncontrolled variables and the number of lessons that the students participated in is the controlled variable. The dependent variables are “progress corresponding to level, progress in solving exercises, and progress in solving word problems. In this case, the F values only refer to the interaction effect (the effect of the method is shown in **Table 4**).

**Table 4** shows that an interaction effect only occurs with respect progress on



**Figure 2.** Average progress of students, the gap grew in relation to age and teaching method.

**Table 4.** Student achievement scores correlated to teaching method and grade: observed averages, fixed averages, standard deviations, and F values.

Grade	4 - 5		5 - 6		4 - 6		F value p
	frontal	alternative	frontal	alternative	frontal	alternative	
<b>No. of students</b>	<b>N = 100</b>	<b>N = 78</b>	<b>N = 70</b>	<b>N = 82</b>	<b>N = 75</b>	<b>N = 67</b>	
<b>Progress in solving exercises:</b>							
<b>Observed average</b>	-4.98 (21.04)	3.85 (17.48)	-2.33 (16.82)	3.53 (16.48)	-8.07 (21.51)	1.86 (16.96)	
<b>Adjusted average</b>	-4.69	3.55	-2.07	3.04	-7.43	1.48	450. S.I.
<b>Average: Beg. of year</b>	74.08 (12.93)	68.56 (16.02)	73.35 (12.69)	68.72 (14.27)	73.68 (13.51)	73.85 (14.22)	
<b>Average: End of year</b>	69.10 (17.79)	72.41 (11.80)	71.02 (12.90)	72.23 (11.14)	65.61 (19.69)	75.71 (13.09)	
<b>Progress in solving word problems:</b>							
<b>Observed average</b>	3.07 (3.55)	6.19 (5.48)	4.81 (2.89)	7.96 (3.61)	2.16 (2.73)	7.85 (5.17)	
<b>Adjusted average</b>	4.55	4.57	6.21	5.36	5.53	5.84	740. S.I.
<b>Average: Beg. of year</b>	37.82 (6.01)	40.81 (8.42)	39.01 (7.03)	47.45 (6.25)	42.81 (7.93)	57.00 (7.52)	
<b>Average: End of year</b>	40.87 (7.61)	47.01 (8.81)	43.81 (7.30)	55.41 (6.44)	44.97 (7.74)	64.85 (5.73)	
<b>Progress on computer level:</b>							
<b>Observed average</b>	4.05 (2.06)	6.08 (4.08)	4.93 (2.04)	8.91 (3.52)	2.69 (2.01)	10.22 (3.83)	
<b>Adjusted average</b>	4.98	5.05	5.81	7.27	4.82	8.95	16.7*
<b>Average: Beg. of year</b>	38.34 (0.52)	42.96 (1.42)	40.01 (0.91)	47.0 (0.85)	43.39 (1.93)	59.37 (0.90)	
<b>Average: End of year</b>	34.42 (0.51)	47.92 (2.92)	44.71 (1.33)	57.32 (1.21)	46.01 (2.53)	69.31 (0.50)	

Legend: S.I. = Statistically insignificant; \* =  $p < 0.5$ . Note: Degrees of freedom (DF) for all F values are 2.459. Post-hoc test for the interaction effect of computer progress are as follows: Grade: 4 - 5, F values: 4.02,  $P = *$ ; Grade: 5 - 6, F values: 13.40,  $P = *$ ; Grade: 4 - 6, F values: 36.71,  $P = *$ .

the adjusted level ( $DF(2.459)$ ,  $F = 16.7$ ,  $p = 0.00$ ) and not for solving problems or verbal questions. A post hoc test conducted to examine the interaction effect demonstrated a clear effect for all grade combinations. F values of the differences between grades five and six, and even more so for the higher grades. This finding also corroborates our second research hypothesis.

The most striking finding is that most students who are taught by the frontal method remain on their original level, while most students taught by the alternative method progressed to a higher level. This corroborates the third hypothesis.

**Two-year follow-up.** MoE regional test scores showed that, two years later, students who were taught using the alternative method retained their lead over those taught with the frontal method: the average scores of the three classes of 6th graders who had undergone frontal instruction (they had been in 4th grade during the study) were 61.7, 61.8, and 62.5, which are substantially lower than the scores of those who had studied in the alternative method (68, 77.4, 84.3). See **Figure 3**.

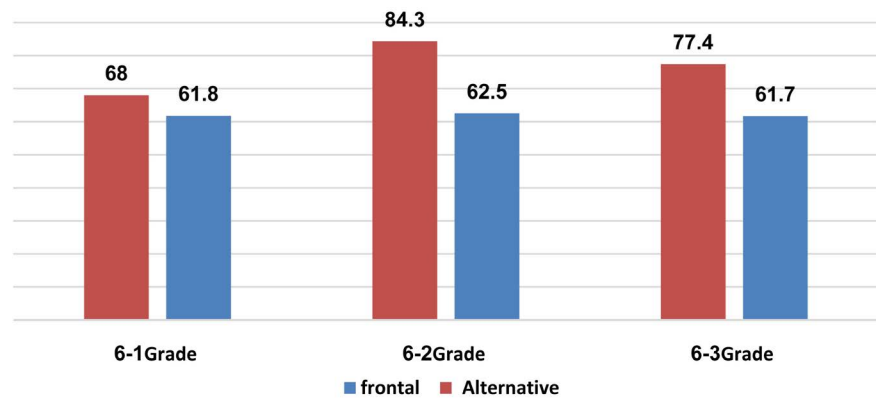
In addition, the percentage of failures in the regional test was compared with the percentage of failures collated from the computer results two years earlier for each of the teaching methods. Of the frontal-method students, 32% failed in the computer and 39% failed the regional test, while only 14%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

The significant positive effect that alternative teaching has on student achievement in mathematics over the frontal method 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 on the computer and progress in solving exercises.

Furthermore, we saw a correlation between teaching method and age: the older the students, the greater the gap in achievement on the computer. This gap was sustained for at least two years, as shown by the results of MoE regional test, where the success rate of students who studied with computer-assisted learning and alternative classroom teaching methods was 84%, compared to 61% for those who did not.

**Hypothesis IV.** The fourth hypothesis, that is, that a significant difference would be found in the mathematical achievements between male and female students who learn in each of the methods, was tested using the number of computer lessons that the student took part in as the statistically controlled variable and the independent variables being teaching method (alternative, frontal) and gender (male, female). The results of the study are presented in **Table 5**, which displays the results of a co-variance analysis.

**Table 5** indicates that there is a clear, interactive effect between teaching method and gender with respect to progress in computer level or progress in



**Figure 3.** Average regional test scores administered to six grade-six classes taught using frontal vs. alternative teaching methods. The test was administered two years after data collection.

**Table 5.** Difference in scores of students' achievement based on teaching method and gender.

Teaching method	Frontal		Alternative		f-values
	M	F	M	F	
<b>Progress on the computer</b>	3.79 (2.39)	3.98 (2.07)	8.38 (4.37)	8.26 (3.96)	5.60
<b>Adjusted mean</b>	5.43	5.47	6.81	6.69	
<b>Progress in solving problems</b>	-6.48 (23.48)	-3.89 (16.18)	3.80 (19.07)	2.45 (14.34)	1.50
<b>Adjusted mean</b>	-5.28	2.79	2.66	1.32	
<b>Progress in solving word problems</b>	3.42 (3.18)	3.16 (3.40)	6.86 (4.70)	7.81 (4.95)	3.60*
<b>Adjusted mean</b>	5.60	5.15	4.77	5.73	

solving problems. Female students who learned with the alternative method progressed in the area of solving word problems more than boys who learned in the same method. In fact, their progress in this area was greater than in any other variable tested between the boys and girls who learned with alternative method. The fourth hypothesis was therefore confirmed, although only partially.

Within the framework of the statistical analysis, we also tested for a triple interaction (teaching method, age, gender) but did not find such an interaction to be statistically significant.

#### 4. Discussion

The hypothesis that a connection exists between teaching method and student performance in mathematics has a solid basis (Swan, Guerrero, Mitrani, & Schoener, 1990; Tiedemann, 2000; Sefer, Hertz-Lazarowitz, & Ben-Tzvi-Meir, 1993; Ben Tsvi-Mayer, Hertz-Lazarowitz, & Safir, 1993), and it is fairly well established that diversified teaching methods that veer from the traditional frontal

one can stimulate and involve all students in the heterogeneous class and allow the introduction of teaching technologies tailored to the needs of the students.

It should be noted that, in all cases, the number of computer classes attended by each student was statistically controlled in the covariance analysis. Advanced comparisons showed that, on the average, students in frontal classrooms attended about half the number of computer classes than those in alternative classrooms. In any case, findings show a gap in achievement favoring students who were taught with the alternative teaching method, regardless of the number of computer classes in which they participated.

The study also shows that the teaching method affects different age groups (grades 4 - 6) differently, that is, the gap in achievement increases with age. It appears that students studying in the alternative method improve over the years while students studying in the frontal method weaken over the years.

The study also compared the progress of students with different levels of accomplishment (weak, average, strong) within each class based on teaching method and found that a significant percentage of weak and average students who were taught with the alternative method advanced in level within their class. In contrast, most frontal-method students remained on the level in which they began the academic year. In other words, weak and average students taught with the alternative method effectively reduced the initial gap between themselves and their classmates while students taught by the frontal method fail to close the gap and are left behind.

#### **4.1. Reasons Underlying the Different Results**

Although the basic conditions for teaching mathematics were similar in the two schools, higher achievement levels were observed in the case when the alternative teaching method was used. This raises the question: What takes place in the classroom in each method that affects achievement?

One aspect is how the teachers relate to their students. Teachers who practice alternate methods relate to their students individually and seek to match teaching method and study material to each one's unique needs and personal capabilities. Also, students take responsibility for their own learning and progress at their own pace and ability. Conversely, teachers using the frontal method consider the class to be a single unit. The method is suitable for the average student: however, strong students quickly lose interest while weak students, being unable to follow the subject matter, do not fully participate and fall by the wayside.

Another aspect concerns the connection between classroom teaching and learning in the computer room. Computer-assisted learning is, for all intents and purposes, individual learning. The alternative method suits the computer room and this affects classroom learning since difficulties that arise in the computer room can be later resolved by the teacher in the classroom and vice versa. This ensures continuity between classroom and computer room and increased effectiveness.

By contrast, frontal teaching is disconnected from the learning process in the

computer room. Difficulties that arise during work in the computer room are not resolved in the classroom, therefore students experiencing difficulties are unable to keep up in the classroom nor progress in the computer room; their loss is double. Teachers that use frontal teaching ignore any diversity revealed in the computer room, do not exploit the possibilities offered by the computer, and continue to teach for the “average” student, resulting, again, in bored high-achievers and confused weak students.

Furthermore, teachers who use alternative teaching consider computer learning to be integral, whereas frontal teachers do not attach importance to the computer's impact on the learning process and miss out on the computer's huge potential for teaching. 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 (Tinajero, Calderon, & Hertz-Lazarowitz, 1993; Järvenoja & Järvelä, 2009). This can explain the differences that occur between schools despite equal conditions in the learning environment. Schools that adhere to frontal teaching methods are less likely to adopt alternate tools—guidance, training, appropriate textbooks, and various teaching aids—tailored to the needs of the students.

#### 4.2. Differences in Student Achievement

The processes that students are exposed to by way of each of the teaching methods are what underlie the disparity in achievement. In the alternative method, the student is the heart of the learning process, takes responsibility for his or her learning, and is actively involved. They receive appropriate assistance in the classroom in response to difficulties they encounter in the computer room and at a level consistent with their personal ability. When they next return to the computer room, they are in control of the material and can progress. Students in the frontal method do not receive an adequate response to the problems they encounter. The learning process in the computer room has no continuation, and in the absence of support and reinforcement, the process stops and progress is arrested.

These findings corroborate those of Hativa and others (Hativa, Shapira, & Navon, 1990; Hacoheh, Osin, Ginosar, Zabar, & Sharon, 1992; Bielaczyc, 2006), 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. In fact, it seems that good students do not need much help from the teacher as their natural curiosity leads to progress regardless of how they learn. Weak students, however, need personalized, focused assistance from the teacher. Because they do not receive this assistance in the frontal teaching method, their progress is halted. However, in the alternative method, they receive the personalized assistance to allow them to progress according to their ability.

**Word problems.** While the study found gaps in student achievement (based



on teaching method) with respect to the indices of computer work and solving numerical exercises, there was no difference in achievements with respect to word problems. A possible explanation lies in the structure of the computer-assisted math curriculum. The computer presents a fixed number of word 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 earlier questions in the sequence. The questions are ranked sequentially from second grade to eighth grade. During computer practice, students are given ten problems. To move to a higher level, they must correctly solve at least six questions on the first try. If they do not, 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 obtain the required level of success for ten-word problems to advance to a higher practice level.

One should note that the method for constructing word problems in the computer-assisted math curriculum has not yet been finalized because of the complexity involved in ranking word-problem difficulty: besides the mathematical sophistication of the problem, their evaluation also involves semantic, linguistic, and logical elements, among others.

### **4.3. Differences in Achievement in Mathematics Based on Teaching Method and Gender**

Within the framework of this study, differences in achievements in mathematics between male and female students were studied correlated to the teaching method used. It was found that in the case of solving word problems, girls taught using the alternative teaching method achieved higher scores than boys similarly taught. The findings detailed above are the basis for the discussion below, which focuses on the differences between male and female with respect to different teaching methods, which is one of the more interesting findings in this study. This finding corroborates those reported by Hertz-Lazarowitz, Calderon, and Ivory, who found that teaching reading and writing in small learning groups positively affected mainly girl students, who did not only progress faster in the subject of Hebrew, but also in mathematics and sciences, and progressed more than boys taught in the same method or girls taught with the frontal method. It seems that in small groups, girls feel more self-confident and are not deterred from actively participating in the learning event. They talk more in this framework and ask more questions, and thus they learn and progress more. On the other hand, in classes where the frontal method was used, the sampling tended to favor the boys (Ben Tsvi-Mayer, Hertz-Lazarowitz, & Safir, 1993).

## **5. Conclusion**

The study shows that the alternative method of teaching (a combination of personalized, group, and class-wide instruction) promotes improvement in weaker and average students whereas with the frontal method the weak and average

students remain weak and average, respectively. This gap continues and even widens over the years. This is explained by the fact that alternative teaching maintains continuity between the classroom learning process and learning activity in the computer room whereas frontal teaching does not. The findings indicate the importance of integrating flexible teaching styles into mathematics teaching.

### Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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