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Computers and 2D geometric learning of Turkish fourth and fifth graders

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Abstract
This research investigated the possible impacts of computers on Turkish fourth-grade students' geometry scores and further geometric learning. The study used a pretest–intervention–posttest experimental design. Results showed that students who did not have computers at home initially had lower geometry scores. However, these differences were minimised with an appropriate intervention containing computer-based Tangram puzzles. This suggests that at schools, it seems more effective to integrate mathematical content and technology in a manner that enables students to do playful mathematical discoveries.

Introduction

Social disadvantage may be an educational handicap, which may lead to further social disadvantages. Students living in poor socio-economic areas usually have limited access to some educational resources such as computers (Olkun & Altun, 2003; Webster & Fisher, 2000). The visual nature of computers can help students develop skills useful in learning subjects with visual content such as geometry. Therefore, the current study aimed at investigating the differences a computer made on students' geometry scores and their further learning of two-dimensional (2D) geometry.

Background literature

Mathematics, computers, and future success

In many countries, achievement in mathematics is an important factor for students' career development. For example, mathematics is one of the subject areas with a high proportion of items on the University Entrance Examination in Turkey. Furthermore, geometry questions occupy nearly 40% of the mathematics section in this exam. There-

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fore, students need a good score in math to be admitted to colleges. Similarly, Fetto (2002) reports that in the USA, half of the students who scored in the upper quartile of their class in eight-grade mathematics went on to earn bachelor's degrees, and 9% received master's degrees. By comparison, only 23% of those who had average eight-grade mathematics scores now have a bachelor's degree, and just 2% have a master's degree.

Literacy and numeracy have long been recognised as a qualification in both schools and workplaces (FitzSimons, 2001). Recently, however, equally strong emphasis has been placed on visual literacy, especially with the prominence of computer technologies. An important dimension in visual literacy is spatial thinking, which supports numerical reasoning and visual judgments (Battista *et al*, 1998). For example, Wheatley and Reynolds (1996) found close parallels between student tiling and numerical activity. Similarly, Battista and Clements (1998) claimed that there was a synergistic effect between numerical and spatial thinking.

Given the importance of mathematics, geometry, and spatial thinking on educational success, it is important to find better ways to teach them. There is ample evidence that real and virtual manipulatives can help elementary school children learn mathematics better (Clements, 1999). Yet computers are still rarely used in the classroom to teach mathematics even in so-called developed countries, such as the USA (Flores *et al*, 2002). On the other hand, many students in the USA have at least one computer at home. Although we do not know the exact percentages in the wider population, in one study whilst 98% of the US 10-year-olds had computers at home, only 25% of the Turkish students had them (Authors, unpublished manuscript). In another survey, Facer *et al* (forthcoming) found that 70% of the children in the UK reported ownership of a home computer. These cross-cultural differences of computer ownership further widen the gap amongst countries as well as amongst social classes.

Certain household materials are important socio-economic status (SES) indicators for exploring both individual and school-level educational effects (Yang, 2003). Olkun and Altun (2003) found striking differences amongst schools located in different socio-economic areas within a province in Turkey in terms of student computer ownership. In one school located in a poor socio-economic rural area, only 4% of the students had computers at home. Seventeen per cent of the students in the other school, located in middle-low socio-economic area, had computers at home. In still another school located in a middle socio-economic area, 27% of the students had computers at home. As the difference in computer ownership is apparent, it seems necessary to investigate the impact of computers on students' geometry learning.

The positive relationship between the SES and student achievement is very well known (see, Yang, 2003). For example, Webster and Fisher (2000) found a strong negative effect of rurality on student mathematics and science achievement. However, they found that in Australia, contrary to common belief, rural schools had more resources than urban schools. They concluded that availability of school resources alone did not

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significantly effect student achievement in mathematics and science. Similarly, Wenglinsky (1998) claimed that the greatest inequities in computer use were not in how often they were used, but in the ways in which they were used. He further reports that poor, urban, and rural students are less likely to be exposed to higher order uses of computers than nonpoor and suburban students because teachers of urban and rural students are less likely to have had professional development in technology than suburban teachers.

Still, one might argue about the other reasons for the relationship between SES and achievement. Breznitz and Norman (1998), for instance, found differences in concentration and academic achievement between low and high SES first grade students. The difference persisted in part to the fourth grade. They attributed the differences in comprehension and arithmetic scores, between the low SES and high SES children, to their concentration abilities. They reported that aggressive–impulsive behaviours, often seen in low SES children, hindered concentration, accentuating learning problems (Breznitz & Norman, 1998). However, using certain educational or otherwise recreational tools such as computers may increase students' level of engagement in learning because the computer is a key item that provides students with many educational (Clements, 1999; Flores *et al*, 2002) and interactive recreational opportunities. Attewell and Battle (1998), for example, found a high correlation between home computers and eighth graders' mathematical achievement. Similarly, the recent Third International Mathematics and Science Study (TIMSS, 1999) reports that on average internationally, students from homes with a high level of educational resources such as computers, had higher mathematics achievement than students from homes with fewer resources.

However, it remains to be investigated *how* having a computer at home and certain computer experiences affect students' mathematics learning. As Wenglinsky (1998) argued, technology may matter, but it depends on how it was used. Therefore, it is particularly important what purposes computers, whether at home or school, are used for.

Computers and geometry learning

One of the most cited uses of computers at home is game playing (ie, Selwyn, 1998). A recent research by Facer *et al* (2003) investigated the ways both elementary and secondary school children use home computers. According to the findings, about 75% students, especially younger ones, use computers for playing games (at least once a week). Rapid developments in hardware technology, increasing capacity of affordable hardware, and increasingly realistic computer graphics also make game playing more attractive.

Computer games can improve spatial skills important for geometry learning (Battista, 1990) and other academic areas (Humphreys, Lubinski & Yao, 1993; Mcgee, 1978; Pallrand & Seeber, 1984; Pearson & Ferguson, 1989; Pribyl & Bodner, 1987; Smith,

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1964). Computer games can improve mental rotation and spatial visualisation (Gagnon, 1985; Greenfield, 1994; Okagaki & Frensch, 1994), but intermittent results indicate that prior experience and other factors mediate such improvements.

Computers can facilitate improvements in spatial skills that may in turn bring more success in geometry. Therefore, the complex relationships between computer ownership, computer treatment, and student geometry learning as part of mathematical achievement bear more investigation.

Definition of terms

Computer ownership

Having an available computer (PC) at home for either instructional and/or recreational uses.

Computer experience

Having done anything on computers either in school or out of school. Obviously, students with computer experience may or may not own a computer at home. They may have used computers at school.

Spatial visualization

Mentally manipulating pictures of objects to solve problems with visual/geometric content.

Research questions

1. Are there significant differences between schools located in different socio-economic areas, in terms of computer ownership and students' initial geometry scores?
2. Are there significant differences between students who have computers at home versus those who do not, in terms of their geometry scores?
3. Are there significant differences between students who have computer experience versus those who do not, in terms of their geometry scores?
4. Can intervention involving computer-based Tangram puzzles influence students' scores on (i) a measure of geometry ability and (ii) on geometry learning as measured by pretest to posttest gain?

Method

Participants

A total of 279 (224 fourth and 55 fifth grade) students recruited from four school sites in a province in Turkey were pre-tested (see Figure 1). Two schools were inner city, one suburban, and one in a rural area. On the basis of their pretest scores and computer experiences, 100 students from the two schools were assigned to experimental and control groups. One of the schools chosen was in a low socio-economic neighbourhood; the other was in a middle socio-economic area. Participation was entirely voluntary.

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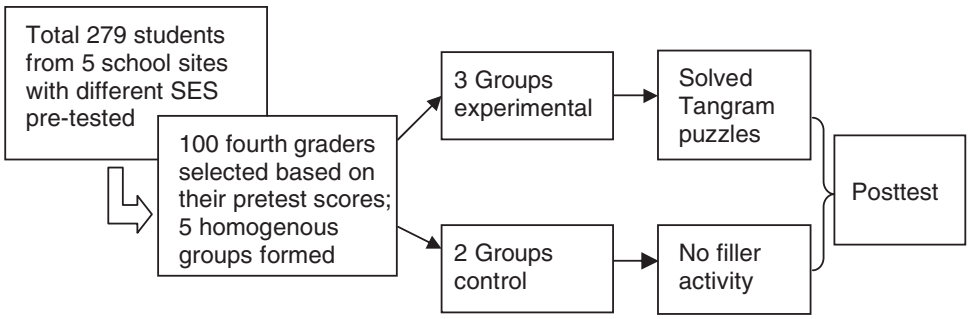

Figure 1: Participants and procedure; SES = socio-economic status

Procedure

A pretest, treatment, and posttest experimental design was utilised for the study (see Figure 1). First, 224 students from the four elementary schools were pre-tested by using a geometry and spatial visualisation test. Additionally, 55 students from one of the schools were also pre-tested to obtain support for the reliability and validity of the measurement instrument. Then, one hundred of the fourth graders were purposefully selected and divided into five equivalent homogenous groups of 20 each based on their pretest scores, so that there were equal number of students with the same mean score in each group. Two of the groups were assigned as control and three others as experimental.

One of the three experimental groups contained students who did not have computer experience. Students in the other two experimental groups (from two different school sites) had computer experience. One of the two control groups consisted of students with no computer experience and the other with computer experience. No action was taken for computer ownership whilst assigning the groups for experimental and control groups. However, in the analysis computer ownership was taken as an independent variable.

During the treatment, students in the experimental groups solved computer-based Tangram puzzles. The students in the control group continued on in their regular classes and were not shown any of the treatment materials. However, they did participate in the pre- and posttests.

The pretests were administered in the spring semester near the end of April 2003. Treatments were carried out in mid-May. The treatment time ranged from 80 to 120 minutes for each student, depending on the time needed to acclimate to the computer and software. After the treatment, which was followed by a five-minute recess, participants took the posttest. The control groups were post-tested in a separate room within the same day.

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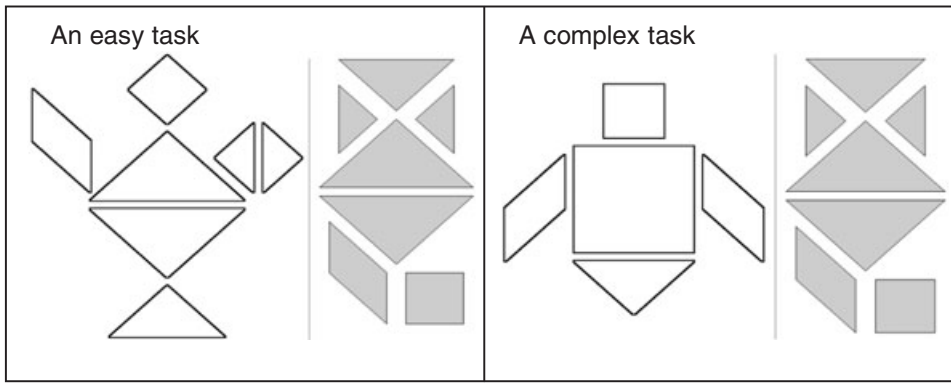

Figure 2: An easy and complex task from the intervention

Instrument
The pretest, modified from an earlier study (Olkun, 2003), was a paper-and-pencil test consisting of 29 questions on 2D geometry. Questions were of four types: spatial, spatio-numeric, mental rotation, and informal area measurement. The posttest was equivalent to the pretest. Although the test had previously been validated and checked for reliability (Olkun, 2003), additional validating was carried out after adding five more items. The reliability coefficients obtained from the pretest with 279 students was sufficiently high (alpha = 0.78, number of cases = 279, number of items = 29). Posttest reliability, computed with 100 fourth graders, was 0.76. The significant differences between fourth and fifth graders' scores provided additional evidence for the validity of the test.

Treatment materials
The treatment provided students with the opportunity to explore and find the relationships between 2D geometric figures. The puzzles were specifically designed to improve students' familiarity with basic 2D geometric shapes and their combinations. There were 40 computer-based Tangram puzzles that ranged from very simple to more complex geometric shapes. Simplicity and complexity were arranged using increasingly more pieces and transformations (ie, rotations) see Figure 2.

Results
The first research question explored the differences amongst schools in different socio-economic areas in terms of both computer ownership and students' initial geometry scores. As seen in Table 1, the higher the SES of the school's neighbourhood the more students have computers at home. A one-way ANOVA test found statistically significant differences amongst the initial geometry scores of students from the four schools investigated, $F(3, 220) = 8.174$, $p < 0.000$. The Tukey HSD (Honestly Significant Difference) post hoc analysis indicated statistically significant differences between school A and school C ($p < 0.001$); school A and school D ($p < 0.001$); and school B and school D ($p < 0.042$). It also showed that the difference between school B and school C

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Table 1: Computer ownership and initial mean geometry scores of fourth graders across schools with different socio-economic status (SES)

Schools	*N*	*Own computer % (n)*	*Mean geometry score**
A (middle SES)	124	27 (34)	10.11
B (mid-low SES)	24	17 (4)	9.83
C (low SES)	51	4 (2)	7.70
D (low SES)	25	4 (1)	7.00
	224	18 (41)	

Note. * Possible maximum score was 29

Table 2: The relationship between computer ownership and initial geometry score

Grade	*Computer Ownership*	*N*	*%*	$\overline{X}$	*SD*	*t*	*p*
Fourth	Yes	41	18	10.68	4.77	2.725**	0.007
	No	183	82	8.85	3.67		
Fifth	Yes	13	24	16.38	6.38	2.368*	0.022
	No	42	76	12.04	5.57		

** $p < 0.01$, * $p < 0.05$

approached statistical significance ($p < 0.074$). These results indicated that students who had computers at home tend to be performing better prior to any intervention.

Whilst these results indicate a significant difference between schools, one can argue that this result could be attributable to other possible controlling variables amongst different SES groups. Therefore, the second research question explored the relationship between computer ownership and geometry scores. An independent *t*-test of students' pretest geometry scores, with computer ownership as the grouping variable, yielded significant differences at both fourth- and fifth-grade levels. Results are presented in Table 2.

To rule out some of the effects of other SES variables, another independent *t*-test investigating the differences in geometry scores between students with computer experiences versus those who did not, showed significant differences between students' geometry scores at the fifth-grade level, but not at fourth-grade level (see Table 3). This finding may indicate that the long-term use of computers may have an effect on students' geometry learning, considering the fact that many students start to use computers at the fourth grade of the school investigated. Similar results are reported in the literature (see Wenglinsky, 1998).

To explore the third research question, an independent *t*-test was run. The *t*-test comparing the pre- to posttest gain for the experimental versus control groups revealed a

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Table 3: The relationship between computer experience and initial geometry score

Grade	*Computer Experience*	*N*	*%*	$\overline{X}$	*SD*	*t*	*p*
Fourth	Yes	125	71	9.70	4.02	1.518	0.131
	No	50	29	8.68	4.04		
Fifth	Yes	32	58	14.50	6.48	2.145*	0.037
	No	23	42	11.08	4.73		

* $p < 0.05$

Table 4: Independent t-test between the experimental and control groups

Groups	*N*	$\overline{X}$	*SD*	*t*	*p*
Experimental	60	3.65	3.83	3.572***	0.001
Control	40	0.95	3.50		

*** $p < 0.001$

significant difference, indicating that the intervention with computer-based Tangrams facilitated geometric learning (see Table 4).

Another research question was, how do computer experience and home computers affect student gains in geometric learning. A univariate analysis of variance was applied to test the main effects between subjects. There is no significant main effect for computer ownership at home. Those who had computers at home (mean = 2.33) did not learn significantly more than those who had no access to computers at home [(mean = 2.54), $F(1, 97) = 0.076$, $p = 0.78$]. Similarly, there is no significant main effect for having any previous computer experience. Those who had earlier computer experience (mean = 2.39) did not learn significantly more than did the others [(mean = 2.59), $F(1, 97) = 0.052$, $p = 0.82$].

The interaction between computer experience and having a computer at home on students' gains on learning geometry was analysed by using a simple main effects analysis. The findings show that there is no significant interaction between computer ownership and computer instruction interaction [$F(2,97) = 0.099$, $p = 0.905$] influencing students' scores on learning geometry.

Discussion

The purpose of the present research was to investigate the impact of (a) a home computer and (b) computer experience, on fourth- and fifth-grade students' initial 2D geometry scores and (c) a specific treatment on fourth graders' further 2D geometry learning. An experimental intervention design with fourth graders was applied. Results showed that students who had computers at home initially had significantly higher geometry scores, but that these differences could be minimised by having students engage in using a somewhat playful computer game, Tangram.

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Students in experimental groups learned more than those in control groups. In the details of the results, however, it was very interesting to find that students who do not have a computer at home also learned as much as those who do have a computer at home when their gain scores were considered. The final scores they (students without computers at home) obtained from the posttest were even slightly higher than those of others. That means that they recovered some of their geometric deficiencies caused by, perhaps, absence of a computer at home. If this assumption is true then it could be said that students' disadvantages can be recovered with appropriate interventions.

Consistent with the previous research (Olkun, 2003; Smith, Olkun & Middleton, 2003), it appears that solving geometric puzzles with computer manipulatives has a positive effect on students' geometric reasoning about 2D geometric shapes. Visual thinking improves through purposefully manipulating objects, either concrete or computer-based (Olkun, 2003). In the present research, a difference in the gained scores between students who used the Tangram software and who did not was observed. During the intervention, students in the experimental groups manipulated (ie, rotated, moved), for example, two equilateral right triangles to make a square, a big triangle, and a parallelogram, or vice versa so that they learned that a square can be divided into equilateral right triangles. In another example, students formed a parallelogram out of right triangles and rectangles or, in some cases, squares. These skills are very crucial to discover the relationships amongst basic geometric shapes and their areas. During the intervention, perhaps actively searching for the solution by turning and arranging the shapes in different orientations, students internalised or formed solid mental images of basic geometric forms in their heads.

When used properly, computers may serve as important tools for improving student proficiency in mathematics and the overall learning environment of the school (Wenglinsky, 1998). Given the importance of integrating computers into content area teaching, there is clearly a need for further research investigating the characteristics of various interventional strategies, such as pair work, and their long-term effects on students' gain scores.

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