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Comparing and Enhancing Spatial Skills of Pre-service Elementary School Teachers in Finland, Taiwan, USA, and Turkey

*Sinan Olkun^a, Glenn G. Smith^b, Helen Gerretson^b, Yuan Yuan^c & Jorma Joutsenlahti^d

^a Ankara University, Faculty of Educational Sciences, Cebeci 06590 Ankara, Turkey

^b South Florida University, Tampa, FL, USA

^c Chung Yuan Christian University, Taiwan

^d University of Tampere, Tampere, Finland

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Abstract

In this study, we compared initial spatial skills of pre-service elementary school teachers in four countries, Taiwan, Finland, United States, and Turkey, and evaluated improvement of these skills by means of interactive computer programs. The study employed a pretest, treatment, posttest design with experimental and control groups. The experimental groups participated in transformational geometry visualization exercises, based on “spatial weaning,” once a week for six weeks of approximately 15–25 minutes each session. The Differential Aptitude Test, Space Relations Subset served as the pre and posttests. Pre-test scores showed a pattern similar to those seen in international comparative studies. Finnish students scored higher, Taiwanese students scored second, USA students placed third, and the Turkish students scored last on a three dimensional test of spatial visualization. For the Turkish and Taiwanese participants, the experimental groups improved significantly more than the control groups, while the Americans and Finnish students showed no such significant improvements. There were various retesting effects, of which the Finnish sample showed the most. Implications for spatial training are discussed.

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Keywords: Geometric transformations; spatial visualization; visual imagery; computer programs.

* Corresponding author. Tel.: +90-312-363 3350; fax: +90-312-363 6145.

E-mail address: olkun@education.ankara.edu.tr

1. Introduction

People who are good at spatial skills are usually good at mathematics and science (Lord & Holland; 1997). Students usually learn these spatial skills in science/mathematics; playing with shapes and manipulatives and visualizing them in their minds (Battista; 1990; Humphreys; Lubinski; & Yao; 1993). However; it is difficult to determine whether people who are good at spatial skills are drawn to spatial activities or are good at spatial skills through practice (Juhel; 1991; Lord & Holland; 1997).

Spatial visualization skills develop over a long period of time as people gain experience through real-world experiences (Robichaux & Guarino; 2000). Thus; it is probably most effective if spatial knowledge is presented in the classroom in connection with everyday experiences; and with virtual and real manipulatives related to concrete everyday objects (Smith; Gerretson; Olkun; Yuan; & Erdem; 2008). Further; it is important for students to become familiar enough with shapes through repeated problem solving that they can easily remember shapes to construct mental images of them (McLeay; 2006).

Major international studies such as Trends in International Mathematics and Science Study [TIMSS] (1999; 2003); Program for International Students Assessment [PISA] (2003; 2006) consistently show that some Far East countries such as South Korea; Taiwan; Japan; Singapore and some North European countries such as Finland; Netherlands are always among the top performing countries among 8th graders or 15 years of ages. For example; Finland; the top performing country in the PISA 2000 reading assessment; has maintained its high level of reading performance while further improving its performance in mathematics and science; placing it now on a par with the East Asian countries; whose performance in mathematics and science had been previously unmatched (PISA; 2003). Similarly; Finland and Korea; and the partners Chinese Taipei and Hong Kong-China; outperformed all other countries / economies in PISA 2006 (PISA; 2006). Additionally; the highest percentage of students at Levels 5 and 6 were found in Korea (27%) and the partner Chinese Taipei (32%) and Finland; Switzerland; Belgium and the Netherlands all had more than 20% of students at these top levels (PISA; 2006).

In these international comparative studies; the United States usually places around the median or the international average. Turkey; on the other hand; usually ranks in the bottom 10 countries of around 40 to 50 participating countries. Given the strong relationship between mathematics performance and spatial skills; in this study we compared initial spatial skills of pre-service elementary school teachers in these four countries and evaluated how these skills might be improved with interactive computer programs. Specifically; we investigated how elementary education pre-service teachers in Finland; Taiwan; Turkey; and the United States learned geometric transformations from structured activities; and how these activities transferred to a non-related standardized test of spatial visualization.

2. Method

Participants were 329 pre-service elementary school teachers from four countries in their third year of college education. Since very few of the participants were male and they were not evenly distributed across the groups we excluded male participants from the study. Also; because some of the participants did not take part in the testing sessions or interventions they were also excluded from the study. Finally; data from 209 female participants was analyzed in the study. The study employed a pretest; treatment; posttest design with experimental and control groups. The experimental groups participated in transformational geometry visualization exercises; based on “spatial weaning;” once a week for six weeks of approximately 15-25 minutes each session. The Differential Aptitude Test; Space Relations Subset served as the pre and posttests (Bennett; Seashore; & Wesman; 1947).

3. Results

Table 1 shows pretest; posttest; and gain score of the students from the four countries. As shown; initially Finnish students scored higher; Taiwanese students scored second; USA students placed third; and the Turkish students scored last on a three dimensional test of spatial visualization. The pattern of results did not change even after the intervention although Turkish students got very close to their American counterparts. ANOVA showed that there were significant differences among the students from the four countries in terms of initial scores [$F(3; 208)=14.68$ $p<.000$]; gained scores [$F(3; 208)=24.10$ $p<.000$]; and final scores [$F(3; 208)=5.90$ $p<.001$].

Table1. Pre and Post test scores on DAT; by country and experimental conditions

| COUNTRY | N | PRE-DAT | SD | POST-DAT | SD | GAIN SCORE |
|---------|----|---------|-------|----------|-------|------------|
| Finland | 68 | 42.53 | 9.31 | 47;70 | 8.50 | 5.17 |
| Taiwan | 44 | 37.95 | 8.14 | 41.50 | 9.29 | 3.55 |
| USA | 72 | 33.46 | 11.35 | 34.25 | 11.40 | 0.79 |
| Turkey | 25 | 30.12 | 8.60 | 34.44 | 8.99 | 4.32 |

Based on the pretest scores; there is a significant difference between Americans and Finnish (Mean difference=9.07 $p<.000$); Turkish and Taiwanese (Mean difference=7.84 $p<.018$); Turkish and Finnish; (Mean difference=12.41 $p<.000$). There are also significant differences between Americans and Taiwanese (Mean difference=7.25 $p<.002$); Americans and Finnish (Mean difference=13.18 $p<.000$); Turkish and Taiwanese (Mean difference=7.06 $p<.045$); Turkish and Finnish (Mean difference=12.99 $p<.000$); Taiwanese and Finnish (Mean difference=5.93 $p<.023$) based on the post test scores. There were significant gain scores for Finnish; Taiwanese; and Turkish students. In order to reveal if the gain scores resulted from the intervention or retesting; we analyzed the data further.

Table1. Pre and Post test scores on DAT; by country and experimental conditions

| COUNTRY | GROUP | N | Pre-DAT ¹ | SD | Post-DAT | SD | Gain Score |
|---------|--------------|----|----------------------|------|----------|------|------------|
| Finland | Control | 26 | 44.08 | 7.9 | 48.65 | 8.2 | 4.58** |
| | Experimental | 42 | 41.57 | 10.1 | 46.67 | 8.9 | 5.10** |
| Taiwan | Control | 20 | 35.80 | 8.3 | 37.30 | 9.8 | 1.50 |
| | Experimental | 24 | 39.75 | 7.7 | 45.00 | 7.3 | 5.25** |
| USA | Control | 32 | 35.50 | 8.8 | 35.44 | 9.9 | -0.63 |
| | Experimental | 40 | 31.83 | 12.9 | 33.30 | 12.5 | 1.48 |
| Turkey | Control | 11 | 31.73 | 9.4 | 34.55 | 9.0 | 2.82 |
| | Experimental | 14 | 28.86 | 8.1 | 34.36 | 9.3 | 5.50** |

¹Possible maximum score: 60. *significant at .05; **significant at .01 level.

There were significant differences between the pretest and posttest scores [$F(1; 208)=50;77$ $p<.000$]. There was a main effect from the intervention; e.g.; the experimental groups learned more than the control groups [$F(3; 209)=5;8$ $p<.001$]. There was also a main effect from country; e.g.; students in different countries responded differently [$F(1; 209)=5;35$ $p<.022$] to the intervention. Further analysis revealed that the experimental groups of Turkish and Taiwanese participants improved significantly more than the control groups; while the Americans and Finnish students showed no such significant improvements. There were various retesting effects in all of the countries except the USA. The largest retesting effect occurred in Finnish students. As shown in Figure 1; experimental groups overall showed a sharper increase from pretest to posttest. There is also an increase in the control group; reflecting a retesting effect. Figure 2 also shows that except the US students all others made improvement.

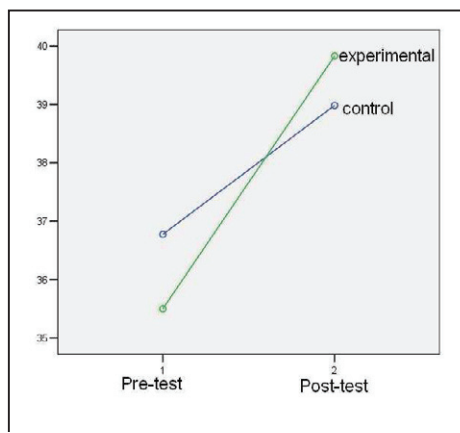


Figure1. Pretest and posttest score of experimental and control groups

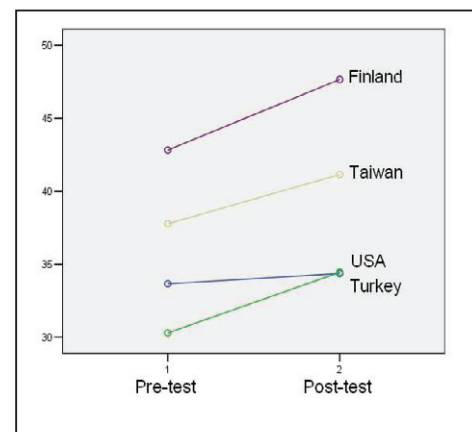


Figure2. Pretest and posttest scores by countries

4. Discussion

This current study utilized a pretest-posttest design with experimental and control groups. We used standardized tests as pre- and posttest measures of pre-service classroom teachers' spatial skills. The results revealed such significant between country differences. Pre-test scores showed a pattern similar to those seen in international comparative studies (see Table 1). Finnish students scored highest; Taiwanese students scored second; USA students placed third; and the Turkish students scored last on a three dimensional test of spatial visualization. The pattern of results did not change even after the intervention although Turkish students got very close to their American counterparts.

On the posttest; the Turkish students had improved statistically significantly more than the US students. The post-test average among the Turkish students was almost identical to the post-test average among the US students. So; even though the Turkish students improved much more; they really only caught up to the US students. The improvement of the Finnish students resulted mainly from retesting. As a result only the students from the two eastern countries; Turkey and Taiwan; improved as a result of intervention while the other students from western countries; USA and Finland; did not.

5. Conclusions & Implications

The results have three important implications: First; they suggest that spatial skills can be enhanced through relevant learning activities such as geometric transformations. Secondly; the results suggest that relevant activities may also affect far transfer and some generalization of spatial skills; i.e.; the interventions were not specifically related to the DAT spatial visualization test used for the pre and posttests. Thirdly; the cross cultural differences may be alleviated through relevant interventions especially for participants who start out weaker in spatial visualization skills.

Why the students in different cultures responded to the training differently is open to speculation. One possibility is cultural differences among the four countries. We claim that the reason that the spatial training was more successful in Taiwan and Turkey than in the USA and Finland is that Turkey and Taiwan have a relatively more formal classroom culture; where students are more likely to fully cooperate with such research projects involving ongoing voluntary activities. In the United States and Finland; there is a relatively more informal classroom culture and more equality between instructors and students that makes such full cooperation less likely. This may also suggest that introducing new teaching techniques; under the guise of research; is likely to be more successful in countries with more formal classroom cultures (Smith; Gerretson; Olkun; Yuan; Dogbey; & Erdem; 2008).

6. References

- Battista; M. T. (1990). Spatial visualization and gender differences in high school geometry. *Journal for Research in Mathematics Education*; 21(11); 47-60.
- Bennett; G. K.; Seashore; H. G.; & Wesman; A. G. (1947). *Differential aptitude tests: Space relations (Form A)*. New York: Psychological Corporation.
- Humphreys; L. G.; Lubinski; D.; & Yao; G. (1993). Utility of predicting group membership and the role of spatial visualization in becoming an engineer; physical scientist; or artist. *Journal of Applied Psychology*; 78(2); 250–261.
- Lord; T. & Holland; M. (1997). Preservice secondary education majors and visual-spatial perception: An important cognitive aptitude in the teaching of science and mathematics. *Journal of Science Teacher Education*; 8(1); 43-53.
- McLeay; H. (2006). Imagery; spatial ability and problem solving. *Mathematics Teaching*; 195; 36–38.
- PISA. (2003). *Learning for Tomorrow's World: First Results from PISA 2003*; OECD.
- PISA. (2006). *Science Competencies for Tomorrow's World Executive Summary*; OECD.
- Robichaux; R.; & Guarino; A. (2000). Predictors of visualization: A structural equation model. Bowling Green; KY: *Paper presented at the meeting of the Mid-South Educational Research Association*.
- Smith; G. G.; Gerretson; H.; Olkun; S.; Yuan; Y.; Dogbey; J.; & Erdem; A. (2008). Stills; not full motion; for interactive spatial training: American; Turkish and Taiwanese female pre-service teachers learn spatial visualization; *Computers and Education* (2008); doi:10.1016/j.compedu.2008.07.011.
- TIMSS. (1999). *International Mathematics Report; Findings from IEA's Repeat of the Third International Mathematics and Science Study at the Eight Grade*. Retrieved on 12-March-2001; at URL: http://timss.bc.edu/timss1999i/pdf/T99i_Math_TOC.pdf.