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Dear Reader,

International Electronic Journal of Elementary Education (IEJEE) is one of the youngest scientific journals in the field of education. This is Nr. 2 of the Vol. 1. We are pleased and been proud of the positive feedbacks that we received for the Nr. 1 from our readers in 2008.

We are encouraged. We realized that we are accomplishing an important work by devoting International Electronic Journal of Elementary Education (IEJEE) for the challenging and contemporary issues in elementary education in different countries in our time.

IEJEE has received overwhelming attention by the international community of researchers. Researchers from Canada to South Korea and from Nigeria to USA and many from the broader Europe have submitted their papers.

I don’t know whether any other new scientific journal has received so much attention at its first issue as IEJEE has done. We realized that we had to expand our circle of editorial board members and reviewers to conduct scientific and ethical defendable reviews within an acceptable time limit. We have so long worked hard and will be working harder in the period ahead.

As we mentioned in the first issue of IEJEE, the main aim of International Electronic Journal of Elementary Education (IEJEE) is to be a channel for the academic friends and researchers of Elementary Education, regardless where they are. As a scientific journal, IEJEE, will be an open channels for researchers from all over the world to make their research accessible for teachers, other professionals and scholars, and decision makers. With such ambitions IEJEE is committed herself to follow ethical and scientific rules of research, submission and publication.

IEJEE is a peer-reviewed electronic journal. It will come out three times a year. A group of researchers from different universities from different countries comprise IEJEE’s editorial team. They have done a great job even though they had busy schedules. I want to express my best gratitude to all of them.

Several researchers wonder whether IEJEE is listed in any index for scientific journals. We are working on that issue. We are already listed in one, and we hope we’ll be listed in several others in this year. We know that IEJEE’s scientific line, quality and published high quality papers will bring her to the place she deserves. IEJEE’s merits are the merits of her authors!

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To be an Editor-in-chief for a young journal in a broad field as Elementary Education, and at the same time getting so much attention internationally is both an encouraging and a demanding job. IEJEE is a product of teamwork and commitment by many. However the job that my friend and colleague Dr. Turan Temur of University of Dumlupinar, has done as coordinator and editor is unique. I want to express my thanks and acknowledgements to him and all the members of the editorial team and to all the researchers that submitted their papers to IEJEE.

Sincerely,

Prof. Dr. Kamil Özerk
Chief Editor
University of Oslo, Norway

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Korean parents' perceptions on the importance of computer usage for themselves and their children: An exploratory study

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ABSTRACT

Many families today have access to computers that help them with their daily living activities, such as finding employment and helping children with schoolwork. Minority families residing in the United States though often do not own home computers. With a greater number of immigrant families arriving to the United States, questions are raised whether parents unfamiliar with the new culture view computers as important teaching tools for themselves and their children. An exploratory study was conducted looking at Korean parents whose children were enrolled in a Southern California elementary school, since this minority group consistently falls within the top ten immigrant sending countries. The study's purpose was to examine parent perceptions on the importance placed on computer usage for themselves and their children. Findings suggest that Korean parents place a high value on computer usage and see it as vital to job success and academic achievement.

Keywords: Korean parents, Korean children, computer use, parent perceptions of computer use

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Introduction

With the latest technological advancements in computer design and the accessibility to global knowledge, we find ourselves connected with world events at a touch of a keyboard. Computers are a part of everyday experiences and families are realizing the indispensability of having access to them. Indeed, multimedia CD-ROMs, software programs, the Internet, and electronic mail have increased people's understanding of computers. Greater understanding has brought greater ownership. Between 1990 and 1997, the percentage of households' owning computers jumped from 15% to 35% (U.S. Dept of Labor, 1999). According to a recent study conducted by the Pew Research Center (2007), computer ownership in the U.S. is at 76%.

In spite of the growing use of household computers in the United States, minority families are often considered non-traditional members of society who often find themselves on the non-technology side of the 'digital divide' (Abrams, 1997; Chakraborty and Bosman, 2005; Hoffman and Novak, 1998; Kominski and Newburger, 1999). That is, the gap between those who have access to and can effectively use information technologies and those who cannot (Wilhelm, 2001). As such, the use of computers or having access to the Internet is still unknown to many minority families (Migrant Education Consortium for Higher Achievement [MECHA], 2001).

Families from minority backgrounds with little or no computer skills are often placed at a disadvantaged. Brogan (2000) points out that the emerging, digital generation (from K through middle-school) has been exposed to computers since birth and use technology as an indispensable part of their lives. These children enter school with technology skills and expectations that are very different from children who have not used a computer before they enter school. Thus, minority children may not receive the necessary guidance from parents who lack computer technology experience.

Parental influence on their children's learning

Parents play an important role in the education of their children (Hoover-Dempsey and Sandler, 1997). They are oftentimes the entry point, the initial contact by which young children are exposed to the function, purpose, and value of a computer, and their attitudes greatly impact those of the child (Sanger, 1997). This phenomenon occurs in most childhood learning situations (Hao and Bonstead-Bruns, 1998; Hoover-Dempsey and Sandler, 1995; Sailor, 2004). For example, if parents hold favorable perceptions of a learning tool, such as computers, then in all likelihood the child will incorporate similar attitudes. Thus, a computer can be beneficial or detrimental to a young learner depending on how it is modeled as a training tool and the attitudes held towards it by the parents. Understanding parental feelings and attitudes towards computers may assist school personnel in determining type, frequency, and theme of homework assignments, thus allowing families to engage in tasks that they are comfortable with.

Parental Perceptions of Computer Use

Although more parents today use computers compared to two decades ago (U.S. Dept. of Labor, 1999; Pew Research Center, 2007), very limited information has been collected on their perceptions of the importance of these technological tools for themselves or their children. The few studies that exist suggest that parents associate computer use with academic achievement and job success. For example, in one early study, Visser (1987) found that parents desired computers as part of their children's education and believed that with computers, achievement scores would increase. In another study (Scherer, 1990), 88 sets of parents were asked to complete a questionnaire as to why they enrolled their 4- and 5-year-old children in computer classes and their attitudes towards the importance of computer competence. The two primary reasons for enrolling their children in these classes were so that they could have fun and learn about computers at an early age. Yet, parents also felt strongly that computers would help them with skills needed for other learning, such as math and reading. Finally, Wentworth and Connell (1995) asked 30 parents to complete surveys on their perceptions of the use of computers for teaching math to their elementary age children. Knowledge of computers was found to be important to the parents and felt that math skills, which they saw as job related, could be taught using this form of technology.

Instead, researchers have concentrated their attention on factors that impact children's computer use, such as their perceptions of technology (Jarvis and Rennie, 1998), the impact of computers on their physical, cognitive, and social development (Anderson and Butcher, 2006; Subrahmanyam, Kraut, Greenfield, and Gross, 2000), and computer use in the home and in the school (Mumtaz, 2001). In addition, there are voluminous pages of statistical figures on the average number of computers in American homes, the socioeconomic status of families who own computers, the increased computer usage by children and adults in the past decade, and the use of the Internet at home, work, and school (Chakraborty and Bosman, 2005; Kominski and Newburger, 1999; U.S. Dept of labor, 1999). Yet, despite the large amount of data collected in these areas, the investigation of parent perceptions on the importance of computer usage has remains relatively neglected.

Minority Families and Computer Use

As scant as the findings are on parent perceptions of computer use within Euro-American families, data on minority parents are nearly non-existent, although there does exist some demographic and descriptive information. For instance, Hoffman and Novak (1998) suggest, from survey findings, that White families are likely to own a computer and access the Internet more often than African-American families. Factors that influence this disparity include income and education. The Migrant Education Consortium for Higher Achievement (2001) reports that the use of computers or having access to the Internet is still unknown to many Latino, migrant families. Also, Kominski and Newburger (1999) state that people of White and 'other' races have much higher levels of computer ownership than African-Americans or Hispanics based on education levels. And, between 1990 and 1997, all minority groups increased their ownership of personal computers (U.S. Dept of Labor, 1999), with Koreans showing the largest percentage point change, expanding from 25% in 1990 to 49% in 1997.

Unfortunately, because of the scarcity of studies on parent perceptions, we are left to extrapolate from research in the area of 'parent aspirations' that families who have a high regard for academic achievement (Hao and Bonstead-Bruns, 1998; Hoover-Dempsey and Sandler, 1995), also recognize and welcome the importance of technological advancements, such as computer usage. But without a thorough and systematic investigation, it will never be known for sure.

Demographic Profile of Korean Families

The minority profile of the United States has been changing dramatically over the past thirty years. Since the passage of the Immigration Act of 1965, an increasing number of Korean immigrants have come to the United States each year (Hurh and Kim, 1990). Among the top ten immigrant sending countries to the United States, Korea has ranked eighth for the past decade (Center for Immigration Studies, 2005), with a total of 1 076 872 residing within this country (Yu and Choe, 2003). Between 1990 and 2002, 278 000 alone immigrated to the United States, with a 34% increase during this period.

In California, Korean families make up 2.7% (N=76 053 families) of the total immigrant population (Yu and Choe, 2003). Orange County is the third largest Korean populated geographic area (N=55 573) within this state. The city of Fullerton, which is located in Orange County and is where the current study was conducted, has 9 093 Koreans residing within its boundary.

The researchers chose Korean families for this exploratory study because of their growing numbers in Southern California schools and because no research has been conducted on their perceptions on the importance of computer usage for themselves and their children. With the continual increase of immigrants into the United States comes the need to understand the importance that minority parents place not only on educational achievement and employment but also on the means by which they and their children hope to attain them. Therefore, the current study was driven by the following questions:

- How often do Korean parents use computers?
- Do Korean parents view computers as important learning tools?
- Do Korean children use computers to complete schoolwork, and if so, are parents involved?
- What role do Korean parents see the schools having relative to children and computer use?
- Do Korean parents see a relationship between computer use and academic achievement?

Method

Participants

The participants in this study consisted of Korean parents whose children were enrolled in grades K through 6th in a Southern California public school. The elementary school has a minority, 85% of the overall student population, 35% of which are English language learners. Students of Korean descent are the largest minority group (53%) at the school. The school is located in a middle- to upper-socioeconomic neighborhood and is within a school district where parent involvement in their children's education is greatly emphasized.

Procedure

The elementary school was selected for this exploratory study because of its large Korean student enrollment. The researchers met with the school principal who was asked to speak with the teachers from grades K through 6th and inform them of the proposed study. The researchers provided the principal with the required number of surveys in English and Korean, who then distributed them to each teacher. The principal placed a two-week deadline for the parents to return the surveys. There was an incentive of an additional recess for classes that had high survey return rates.

Instrument

A survey, consisting of 24 questions, was disseminated to the families of the entire school population (N=957). The first section of the instrument was comprised of 9 demographic questions, such as parent minority and educational background. The second section of the survey consisted of 6 questions that asked parents about their perspectives on personal computer usage. The third section consisted of 9 questions which asked for parents' attitudes on their children's computer use (See Appendix for copy of parent survey).

Results

Out of a total of 957 surveys disseminated, 596 (62%) were returned. Of the 596 surveys returned, 356 (60%) were from Korean parents. For the purpose of this paper, only data from surveys returned by Korean parents will be presented since the study's goal was to look specifically at this minority group.

Demographic Characteristics

The respondents consisted of 356 Korean parents whose children were enrolled in grades K through 6th. Two hundred thirty one females (64.9%) filled out the surveys as compared to 122 males (34.3%). Three respondents did not identify their gender. As shown in Table 1 below, two thirds of the parents (75.3%; N=268) were primarily 1st generation to the U.S. (See Appendix, survey question #2, for definition of generation level).

Table 1 Parents' Generation Level

Generation	N	%
1st	268	75.3
2nd	66	18.5
Missing Data	22	6.2
Total	356	100

Table 2 shows that the majority of parents (72.2%; N=257) had attended college with a smaller proportion of respondents (17.1%; N=61) having completed post graduate work. Annual income for almost half of the respondents (49.7%; N=177) varied between $46,000 and $60,000+ (Table3).

Table 2 Parents' Education Level

Schooling Completed	N	%
High School	35	9.8
Some College	100	28.1
College Graduate	157	44.1
Post Graduate	61	17.1
Missing Data	3	.8
Total	356	100

Table 3 Parents' Annual Income

Salary Range	N	%
Below $30 000	26	7.3
$31 000-$45 000	30	8.4
$46 000-$60 000	47	13.2
Over $60 000	130	36.5
Missing Data	123	34.6
Total	356	100

Table 4 indicates that the respondents' children were primarily older elementary school students (i.e., 4th, 5th, and 6th) (56.2%; N=199).

Table 4 Child's Grade Level

Grade	N	%
K	29	8.1
1st	36	10.1
2nd	37	10.4
3rd	49	13.8
4th	68	19.1
5th	60	16.9
6th	71	19.9
Missing Data	6	1.7
Total	356	100

Descriptive Characteristics

In relation to computer ownership and usage, the majority of parents (97.8%; N=348) disclosed that they had a computer at home, with most accessing it on a daily basis (79.2%; N=282). On average, there were at least one and a half computers in each respondents' home (M=1.74; SD=.861). Most parents (90.7%; N=323) also had Internet capability on their home computer, with over two thirds of the respondents (80.3%; N=286) using the Internet on an almost daily basis (Table 5).

Table 5 Internet Access

How often	N	%
Every day	173	48.6
1-3 times a week	113	31.7
Once every two weeks	13	3.7
Once a month	9	2.5
Other	13	3.7
Missing Data	35	9.8
Total	356	100

Parents' Computer Usage

A majority of parents (77.5%; N=462) have used a computer for at least three years or longer. Almost all respondents (95.5%; N=340) overwhelmingly agreed that computers were important learning tools, and that knowing how to operate a computer was related to acquiring successful jobs (88.5%; N=315). In a surprise finding, nearly two thirds of the parents (73.8%; N=263) felt that using a computer at home was more helpful than going to the library, and yet, almost half the respondents (48%; N=171) reported that they could get by without the aid of a computer in their home.

Children's Computer Usage

Parents generally agreed that it was important that their children have access to a computer at home (87%; N=310), as well as at school (91.8%; N=327); with a slightly smaller proportion of respondents (80%; N=285) reporting that their children used a computer to complete homework assignments. Many parents (79%; N=281) also felt that learning to use a computer should be taught in school just like any other content subject, so that children could begin from an early age developing study habits and doing homework with the aid of this tool (84.8%; N=302).

Many parents agreed (81.1%; N=289) that children knowing how to use a computer would do well in school. A smaller number of parents (69.7%; N=248) reported getting involved in their children's education with the help of a computer. On the subject of monitoring, almost all parents (90.4%; N=322) saw it as their responsibility to supervise what their children viewed on the computer. Finally, most parents (89%; N=317) saw a positive relationship between their children knowing how to use a computer and being successful in life.

Discussion

Current research findings suggest that minority families are less likely to own household computers and have access to the Internet than White families. They often fall on the non-technology side of the 'digital divide' which places them at risk of not achieving academically and/or occupationally. Therefore, the goal of this exploratory study was to look at a sample of minority (Korean) parents and their perceptions on the importance of computer use for themselves and their children.

Relative to the questions driving the investigation, the findings suggest that most Korean parents rely heavily on home computers. They tend to access them on an almost daily basis. With an average of one and a half computers per household, it was expected that usage would be frequent, with family members having easier access than if they waited in line at a public library or 'cyber' café. This finding was not surprising given that the parents in the study reside in middle- to upper-socioeconomic neighborhoods, with many having attended college and earned substantial annual incomes. It was also not surprising that almost all the respondents viewed computers as important learning tools, thus complementing studies by Hoffman and Novak (1998), and Chakraborty and Bosman (2005), that higher education and income levels positively influenced computer usage and ownership.

In addition, not only have most of the parents used computers for at least three years or longer, they also seemed to be involved in their children's education with the help of computers. That is, many parents reported that their children completed homework assignments using a computer while they assisted. Parents saw schools as having a vital role in educating their children on the use of computers. They strongly felt that schools should provide access to computers, and that computer training should be made part of the overall school curriculum, such as math and English. Finally, parents believed that learning about and using computers would assure success for their children in school and in finding a job.

As previously mentioned, a surprise finding was that nearly two thirds of the parents felt that operating a computer at home was more helpful than using the library. Yet, when asked if they could get by without the aid of a computer at home, nearly half of the parents responded yes. This indeed seemed to be a curious anomaly. On the one hand, there is an extensive, daily reliance on computer technology by Korean families. But on the other, parents feel that they could continue to perform daily functions without these electronic devices.

It can only be speculated why this disparity exists since no qualitative data were collected. Two hypotheses are offered. The first is that although Korean parents and their children are users of today's technological tools, they are not "addicted" to them. For example, they may operate computers to access the Internet, send email messages, and word process, but these are functions that can still be performed by cell phones, library resources, post offices, and typewriters. The second reason is that many of the parents may not have understood the question being asked of them. Since a large number of respondents were 1st generation to the U.S. and English was not their first language, they may have inadvertently reversed the meaning of the question. That is, by agreeing to the question, they thought they could *not* get by without the aid of a computer. This particular question will have to be re-examined more closely for future studies.

In light of the study's findings, future research on this topic is necessary. A limitation of the current study is its focus on a school located in a middle- to upper-socioeconomic neighborhood. A similar investigation that looks at Korean parents from a school located in a lower-socioeconomic neighborhood would be beneficial to compare to the current study. This would allow for additional exploration on whether socioeconomic backgrounds play a key role in perceptions on computer importance.

Parent minority is another key element that would be worth exploring in greater detail. An investigation of parent perceptions within a range of minority groups (and socioeconomic backgrounds) would help provide additional insights that could possibly lead to useful comparisons. In particular, the study of immigrant parent groups, in and of themselves, would also be revealing.

In addition to the two areas described above for future research, we recommend employing a different research framework. The use of qualitative research methodology would allow a rich data set to be collected that could help provide deeper insights into parent responses. Thus, a follow up study that includes individual and group interviews of the Korean parents who were part of the original study would be advised.

Additionally, any new studies conducted should use a mixed-method approach (i.e., qualitative and quantitative).

Continued research with the current study could move in several complementary directions based on investigations by Wellington (2001), who studied computer use at home in the United Kingdom. He proposed various questions for future research that we believe relate to the current study. We suggest though modifying his questions by including the element of minority. They include;

- What relevant experiences related to computer use in the home do children bring to school from various minority groups?
- What is appropriate use of computers in the homes of various minority groups?
- Do different minority groups use computers in the home for different purposes?
- What impact does having computers at home have on achievement of students from various minority groups?
- How should teachers design learning tasks for individuals at home that include minority themes?

The answers to these questions would give teachers, parents, administrators, and policy-makers useful data to consider as they make decisions about computer use in schools and homes.

In conclusion, various findings of this study were similar to previously reported investigations on parent perceptions of computer usage. Demographic variables, such as income and education, were found to be linked to computer ownership and its use when parents had attended college and earned substantial annual incomes. New information was also presented above, such as parent attitudes towards monitoring their children's computer time and the role of the schools in providing computer classes. Additional studies of this nature are highly recommended given the dynamic minority and population changes that are currently occurring in the United States.

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Appendix

Parent Survey

1. Person filling out this survey: ___male; ___female

2. We would like to know how long you have lived in the U.S. based on your generation status. For example, 1st generation is someone who immigrated to the U.S. from another country, 2nd generation is anyone born to parents who immigrated from another country, and so on: ___1st; ___2nd; ___3rd; ___other (please identify) _________

3. How would you describe your minority background: (for example, Korean, Mexican American, etc.) : _________

4. What grade is your child in? _______________

5. What was the last grade you completed in school? ___Elementary School; ___High School; ___Some College; ___College Graduate; ___Post Graduate

6. Do you have access to computers on a daily basis? ___yes; ___no.

7. Do you have a computer at home? ___yes; ___no.

If yes, how many computers do you have at home? __________

8. Do you have access to the Internet at home? ___yes; ___no.

If yes, how often do you access the Internet at home?

___Every day ___1 to 3 times-a-week ___Once every-two-weeks ___Once a-month ___Other

9. What range does your family's annual income fall between? (This question is optional)

___ 0-$15,000 ___$16,000-$30,000 ___$31,000-$45,000 ___$46,000-$60,000 ___over $60,000

Parents' Computer Usage

Instructions: Please circle the response that best describes your feelings about your computer usage.

10. My knowledge of using the computer is:

I do not know how to use the computer	I'm learning to use the computer	I have used the computer for at least 1 year	I have used the computer for at least 3 years	I have used the computer for at least 5 years

11. If I don't know how to use a computer, I would like to learn:

Strongly disagree	Somewhat disagree	No comment	Somewhat agree	Strongly agree

12. Computers are important learning tools:

Strongly disagree	Somewhat disagree	No comment	Somewhat agree	Strongly agree

13. Those who have successful jobs know how to use the computer:

Strongly disagree	Somewhat disagree	No comment	Somewhat agree	Strongly agree

14. Using a computer at home is more helpful than going to the library:

Strongly disagree	Somewhat disagree	No comment	Somewhat agree	Strongly agree

15. I can get by without having a computer in my home:

Strongly disagree	Somewhat disagree	No comment	Somewhat agree	Strongly agree

Children's Computer Usage

Instructions: Please circle the response that best describes your feelings about your child's computer usage.

16. It is important that my child has access to computers at home:

Strongly disagree	Somewhat disagree	No comment	Somewhat agree	Strongly agree

17. It is important that my child has access to computers at school:

Strongly disagree	Somewhat disagree	No comment	Somewhat agree	Strongly agree

18. My child uses the computer for help in homework:

Strongly disagree	Somewhat disagree	No comment	Somewhat agree	Strongly agree

19. My child should be taught how to use a computer as much as she/he is taught other subjects like math or reading:

Strongly disagree	Somewhat disagree	No comment	Somewhat agree	Strongly agree

20. It is important that my child learns how to use a computer so they study and do their homework:

Strongly disagree	Somewhat disagree	No comment	Somewhat agree	Strongly agree

21. Knowing how to use a computer will help my child do well in school:

Strongly disagree	Somewhat disagree	No comment	Somewhat agree	Strongly agree

22. I get involved in my child's education with the help of a computer:

Strongly disagree	Somewhat disagree	No comment	Somewhat agree	Strongly agree

23. Parents should monitor their children’s computer usage:

Strongly disagree	Somewhat disagree	No comment	Somewhat agree	Strongly agree

24. My child will need to know how to use a computer in order to be successful in life:

Strongly disagree	Somewhat disagree	No comment	Somewhat agree	Strongly agree

Thank you for your time in filling out this survey!

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The effect of metacognitive strategy training on mathematical problem solving achievement

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ABSTRACT

The purpose of this study was to investigate the effect of using metacognitive strategy training on mathematical problem solving achievement. The study took place over a nine-week period with 47 fifth grade students. The experimental group (n=24) instructed to improve their metacognitive skills. At the same time the students in the control group (n=23) received no additional activities and continued their normal lessons. Students were pre- and post-tested with the Mathematical Problem Solving Achievement Test and Turkish version of Metacognitive Skills and Knowledge Assessment (MSA-TR). The results indicated that students in the metacognitive treatment group significantly improved in both mathematical problem solving achievement and metacognitive skills.

Keywords: *Metacognition, metacognitive strategy training, metacognitive skills, problem solving, problem solving achievement.*

Introduction

Whatever its source is, a real-life problem or a scientific one, a problem is a phenomenon requiring an individual to choose a strategy and make a decision for a solution in any encountered situation (Van De Walle, 1989). Since 1980s, many instructional programs regarding the mathematics have been reformulated as being problem solving oriented (NCTM, 1989). Mathematical problem solving is generally discussed together with heuristics designed by Polya (1988). However, another equally effective element, key to success in problem solving, is metacognition (Lester, 1994). Research on problem solving shows that it is not sufficient to learn procedures and problem solving heuristics (cognitive content) such as defining the problem, planning, carrying out a plan, testing and checking a solution (Lester, 1994). It is not enough to

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know what to do, but also when to apply such strategies (McLoughlin and Hollingworth, 2001). An effective use of cognitive content is possible only through metacognitive skills.

Metacognition means an individual's awareness of his own thinking processes and his ability to control these processes (Flavell, 1979; 1999; Huitt, 1997; Hacker and Dunlosky, 2003; Jager, Jensen and Reezigt, 2005). It is observed that modern studies discuss the metacognition under two main headings: Metacognitive knowledge and metacognitive control (Flavell, 1979, 1999; Nelson and Narens, 1990; Otani and Widner, 2005; Sungur, 2007). Metacognitive knowledge, in one case, refers to one's knowledge and beliefs in his mental resources and his awareness about what to do. It also mathematically refers to the mathematical processes and techniques students have and their ideas about the nature of mathematics. Metacognitive knowledge means one's own cognitive skills; own cognitive strategies and knowledge about what to do under which circumstances (Flavell, 1979). Metacognitive knowledge requires one to accurately and exactly define his/her thought or knowledge. An individual's ability in problem solving depends on effective use of his/her knowledge. If an individual does not have a decent perception about his/her knowledge, he/she can consider, for example, being a successful student in problem solving as a hard work. In other words, approaches to the problem and insights into how to solve a problem is related to how accurately an individual assesses his/her knowledge (Flavell and Wellman, 1977). However, metacognition requires one, besides the knowledge mentioned above, to use this knowledge effectively. The ability to use metacognitive knowledge, on the other hand, is called metacognitive control (Özsoy, 2007). Also called metacognitive strategy, the metacognitive control skills consists of leading mental operations in metacognitive processes and can be defined as the ability to use the metacognitive knowledge strategically in order to attain cognitive objectives (Schraw and Moshman, 1995; Desoete, 2008). The literature focuses on four metacognitive skills; prediction, planning, monitoring and evaluation (Brown, 1980, Lucangeli and Cornoldi, 1997; Deseote, Roeyers and Buysse, 2001; Deseote and Roeyers, 2002).

Metacognitive control/regulation is considered as the ability to use knowledge to regulate and control cognitive processes. Metacognitive control is related with metacognitive activities that help to control one's thinking or learning (Özsoy, 2008). Students having the prediction skill think about the learning objectives, proper learning characteristics, and the available time. Prediction skill enables students to predict the difficulty of a task, by this way they use that prediction to regulate their engagement related to outcome. The selection of appropriate strategies and allocation of resources closely related with the prediction skill (Desoete, 2008). Monitoring refers to one's on-line awareness of comprehension and task performance. The ability to engage in periodic self-testing while learning is a good example (Winnie, 1997). Planning is a deliberate activity that establishes sub-goals for monitoring engagement with a task (Winnie, 1997). Students having the evaluation skill appraise the products and regulatory processes of their learning. Students can re-evaluate their goals and conclusions. Evaluation enables students to evaluate their performance on the task, students can compare their performances with each other and they can use the result of comparison to locate the error in the solution process (Lucangeli, Cornoldi, and Tellarini, 1998).

Metacognitive strategy instruction

Metacognitive awareness may arise at the age of 4–6 years (Demetriou and Efklides, 1990). There is a substantial increase in metacognitive development during the primary school years as a function of age and experiences (Flavell, 1988). However, instruction has a more impact on the acquisition of metacognitive skills than growth has (as cited in Subaşı, 1999: Gage and Berliner, 1988; Veenman, Wilhelm and Beishuizen, 2004). Metacognitive instruction which plays such an important role in regulation of cognitive processes is based on the assumption that when an individual perceives how cognitive processes operate, he/she will be able to control these processes and use them in a more efficient way by arranging them for a more qualified learning (Ulgen, 2004). On the condition that instructional arrangements which will develop metacognitive skills contain characteristics such as active participation and learner's controlling the process, they can improve metacognitive skills through instruction (El-hindi, 1996). Instruction of metacognitive strategy enables the learners to reach a high-level cognitive process by allowing them to discover appropriate problem solving processes and use these processes under different conditions (Victor, 2004). On the other hand, it drives forward the internalization of knowledge through definition of the problem, asking questions to himself/herself, establishing connections between existing and new information, monitoring the learning process and associating learned information with current situations (Ashman and Conway, 1997).

It is seen that studies on the instruction of metacognitive strategy use methods such as developing supportive social environment (Schraw, 1998), giving feedback (Cardelle-Elawar and Corno, 1985) interactive problem-solving (Schraw, 1997; Kramarski, Mevarech, Liebermann, 2001), asking reflective questions (Schoenfeld, 1985; Mayer, 1998), conditional knowledge discussions (Schraw, 1998) and using control lists (Schraw, 1998). However, if we are to make a general classification, studies on this topic use two basic approaches as strategy instruction and supporting social environment.

One of the strategies which can be used for developing metacognition within the framework of constructivist learning is to encourage the students to ask questions themselves. In order to enable the students to ask questions themselves about what they are doing and establish an appropriate discussion environment, it is important to ask effective questions. Effective questions contribute to problem solving, trigger the thinking process and stimulate the imagination. Asking appropriate questions activates the metacognitive skills of students (Hacker and Dunlosky, 2003). While especially questions asked by teachers, such as '*What about next?*', '*What do you think?*', '*Why do you think so?*' and '*How can you prove this?*' trigger the thinking and contribute to the development of metacognitive abilities (Yurdakul, 2004).

It is observed that the method commonly used and proposed to be used theoretically in studies on metacognitive strategy instruction is instructing through structured activities (Schoenfeld, 1985; Marge, 2001). This approach is based on the fact that metacognitive skills should be taught together with activity content. When the issue is instruction of metacognition, the most significant advantage of structured instruction is that it not only teaches the skills but also provides opportunities for teaching where, when and how to use these skills. Metacognitive strategy instruction using structured activities provides the learner with both knowledge of cognitive processes and strategies, and experience or practice in using both cognitive and metacognitive strategy and evaluating the outcomes of their efforts (Wilburne, 1997; Goldberg and Bush, 2003). Simply providing knowledge without experience or vice versa does not seem to be sufficient for the development of metacognitive control (Livingston, 1996).

Metacognition and problem solving

Failure in problem solving is generally resulted from failing to organize the mathematical operations, to choose the most effective method, to analyze, to understand the point of problem and to monitor and control operations carried out (Victor, 2004). It is a known fact that students with high metacognitive skills perform better in problem solving (Schoenfeld, 1985; Lester, 1994; Desoete, Roeyers and Buysse, 2001). It has been observed that during problem solving process they are more controlled; they try to break the complex problems into simple parts and they ask questions themselves for clarifying their thoughts. Schoenfeld (1985) states that when one encounter with failures in problem solving techniques, control skills (metacognition) will be helpful for applying strategies successfully.

Metacognition plays an important role during each level of mathematical problem solving. Goos, Galbraith and Reenshaw (2000) stated that a failure in metacognitive skills ensures the corresponding failure in mathematical thinking and problem solving. Problem solving process requires analyzing the given information about the problem, organizing the possessed information, preparing an action plan and assessing all the operations carried out. These operations of problem solving process require one to arrange each level and step and make decisions at the same time. And all these operations performed during the process are skills which constitute the character of metacognition (Yimer, 2004). For that reason, metacognition is a necessary skill for being successful in problem solving (Victor, 2004). McLoughlin and Hollingworth (2001) stated that studies on problem solving have suggested that problem solving operations such as definition of problem, practice, and controlling the outcome are not enough for learning. It is not sufficient to know what to do. It is necessary to know when to apply similar strategies, too (McLoughlin and Hollingworth, 2001). According to Montague (1992), three most commonly used metacognitive skills during problem solving are self-instruction, self-questioning and self-monitoring. Self-instruction helps children to determine and manage previously used problem solving strategies while working on a problem. Through the introduction of internal dialogues, self-questioning enables them to systematically analyze the given information about the problem and manage appropriate cognitive skills. Self-monitoring allows children to monitor their own general performances during problem solving operations and be sure about the appropriateness of the strategies they use (Victor, 2004).

Researches on problem solving revealed that the students cannot reach the intended success level (Schoenfeld, 1985; Polya, 1988; Özsoy, 2005; Tertemiz and Çakmak, 2003). In literature metacognition has been found essential to come to successful learning (Desoete, Roeyers, and Buysse, 2001; Pugalee, 2001; Teong, 2002). Studies on metacognition have proven that there is a strong correlation between problem solving and metacognition and that the students with a higher level of metacognitive skills become successful in problem solving (Schoenfeld, 1992; Mevarech and Kramarski, 1997). Artz and Armour-Thomas (1992) point out that the main reason underlying the failure of students in problem solving is that they cannot monitor their own mental processes during problem solving. Metacognition may affect how children learn or perform mathematics. Students must learn how to monitor and regulate the steps and procedures used to meet the goal of solving problems. Academically successful students acquire the self-understanding that supports effective strategies to solve problems (Garrett, Mazzocco and Baker, 2006). In addition, the study conducted by Deseote, Roeyers and Buysse (2001) indicated that metacognitive knowledge and skills account for 37 percent of the achievement in problem solving. Lucangeli, Galderisi and Cornoldi (1995) found that metacognitive training positively affects problem solving. Studies conducted with this purpose in mind suggested that there exist positive and meaningful increases in the achievement of children using instruction activities towards developing metacognitive skills (McDougall and Brady, 1998; Naglieri and Johnson, 2000; Teong, 2002; Victor, 2004, Özsoy, 2007).

Present study

By taking into account the methods used in previous studies on an instruction towards developing metacognitive strategy, this study is based on the method 'structured activities' and uses problem-based learning activities. The method used has been named as 'metacognitive strategy instruction using problem solving activities'. This method also covers several methods and strategies which were used separately in previous studies and proved successful (giving feedback, interactive problem solving, asking reflective questions, etc.).

The present study was designed to examine the effect of metacognitive strategy instruction in mathematical problem solving achievement. In particular, the study was designed to seek answers to the following research questions: (a) Does the metacognitive strategy instruction in fifth grade primary school have an impact on mathematical problem solving achievement? (b) Does metacognitive strategy instruction using mathematical problem solving activities have an impact on metacognitive knowledge and skills?

Method

Design

A quasi-experimental design, with pre- and post-test measurements and two groups (experimental and control) was employed. The dependent variable was 'problem solving achievement' as measured by MPSAT (Mathematical Problem Solving Achievement Test). The independent variable of the study was metacognition as measured by Metacognitive Knowledge and Skills Assessment- Turkish version. The inventory originally named as MSA by Desoete, Roeyers and Buysse (2001). Classes randomly assigned as treatment and control group. Only students in the treatment group received metacognitive strategy instruction. Students in the control group continued their normal lessons but they also solved the problems studied in treatment group.

Participants

The participants of the study consist of fifth-grade students (mean age 11.2) studying in one of the public primary schools in Ankara, in Turkey. The school selected conveniently. 47 students (23 girls and 24 boys) took part in the study. 24 of students were in experimental group, and 23 of them in control group. Both groups have been pre-tested and the results have been compared in order to study the equivalence of the groups. However, because the group size is small, Kolmogorov-Smirnov test has been used in analyzing whether the groups display a normal distribution or not. As a result of this test, it has been observed that the group displays a normal distribution (P=.729, p>.05). t test has been conducted in order to find whether there is a considerable difference between the groups in terms of pre-test results. The results of this study have been presented in Table 1.

Table 1 Comparison of pre-test results of groups

Test	Group	N	M	SD	df	t	p
MPSAT	Experimental	24	25.42	12.07	45	1.193	0.239
	Control	23	29.13	11.64			
MSA-TR	Experimental	24	118.33	47.73	45	0.203	0.840
	Control	23	115.52	47.35			

As can be seen in Table 1, there is no significant difference between pre-test mean scores achieved by experimental and control groups in both MPSAT and MSA-TR. These results are t(45)= 1.193 (p>.05) for MPSAT and t(45)= .203 (p>.05) for the MSA-TR. In accordance with these results, it has been concluded that there is no significant difference between the groups. For these reasons, it has been found appropriate to carry out the study on the groups. Upon evaluating the equivalence of the groups, one of them has been assigned as treatment group and the other as control group randomly. The teachers of treatment and control groups are equivalent of each other in terms of age, gender, fields of graduation and professional experience.

Instruments

Mathematical Problem Solving Achievement Test (MPSAT). Used in the study with the aim of measuring the mathematical problem solving achievement, this test has been developed by the researcher. MPSAT consists of 20 items, each of which has four options. In order to minimize the effect of differences in mathematical knowledge among students taking the test, this test included only question which can be solved using four mathematical operations (addition, subtraction, multiplication, division). Also, with the aim of ensuring the compatibility of the questions with student levels (fifth grade of primary school), questions prepared compatible with the Primary School Curriculum implemented by the Ministry of National Education (MEB, 2004). Also, during the preparation of MPSAT, we focused on testing the behaviours which are compatible with Polya's (1988) four stages (understanding the problem, planning, carry out the plan, look back). The analysis results regarding the pilot study carried out on 44 fifth-grade students have been presented in Table 2.

Table 2 Results of pilot study for MPSAT

N	Number of items	M	SD	Pj	KR-20
44	20	11.8	3.6	.56	.84

As can be seen in Table 2, the reliability (KR–20) of MPSAT, which have been re-developed in accordance with pilot study results, is .84 and its mean difficulty (Pj) is .56. It has been found appropriate to use the MPSAT, which have been prepared by the researcher in accordance with the analysis results explained above and positive opinions of field specialists, with the aim of data collection.

Metacognitive Skills and Knowledge Assessment (MSA-TR). In order to measure the metacognitive knowledge and skills of students, an adapted version of MSA (Metacognitive Skills and Knowledge Assessment) (Deseote, Roeyers and Buysse, 2001) was used. The MSA is a multi-method inventory in which the predictions are compared with the student performance as well. The MSA assesses two metacognitive components (knowledge and skills) including seven metacognitive parameters (declarative, procedural, and conditional knowledge, and prediction, planning, monitoring, and evaluation skills (Desoete, Roeyers and Buysse, 2001). In the measurement of "declarative knowledge", children are asked to choose the easiest and the most difficult exercise out of five and to retrieve their own difficult or easy addition, subtraction, multiplication, division or word problem. In order for this hard/easy distinction to be made and graded properly, these operations have been determined through a test applied to fifth grade students of a primary school, in accordance with the method followed during the development of original inventory. As a result of this process, the operations have been placed in the inventory in a way that will grade the least successfully answered questions as the hardest and the most successfully answered ones as the easiest. The exercises on "procedural knowledge" require children to explain how they solved exercises. "Conditional knowledge" is assessed by asking for an explanation of why an exercise is easy or difficult and asking for an exercise to be made more difficult or easier by changing it as little as possible (Desoete, Roeyers and Buysse, 2001). In the assessment of "prediction", children are asked to look at exercises without solving them and to predict whether they would be successful in this task. Children might predict well and solve the exercise wrongly, or vice versa. Children were then scored on 'evaluation' doing the exercises on the same rating scale. The answers were scored and coded according to the procedures used in the assessment of prediction skills. For "planning", children had to put 10 sequences necessary to calculate in order. When the answers were put in the right order the children received 1 point. The following types of questions measured 'monitoring': What kind of errors can you make doing such an exercise? How can you help younger children to perform well on this kind of exercises? Complete and adequate strategies were awarded 2 points. Hardly adequate but not incorrect strategies received 1 point. Answers that were neither plausible nor useful did not receive any points (Desoete, Roeyers and Buysse, 2001).

The inventory consists of 160 items and through this inventory a student can score a minimum point of 0 and a maximum point of 360. During the development process of the inventory (MSA), the test-retest correlation has been r=.81 (p<.0005) in the analyses ascertained by Desoete, Roeyers and Buysse (2001). To examine the psychometric characteristics of the metacognitive parameters, Cronbach alpha reliability analyses were conducted by the developers. For declarative knowledge, procedural knowledge, and conditional knowledge Cronbach α's were .66, .74, and .70, respectively. For prediction, planning, monitoring, and evaluation Cronbach alphas were .64, .71, .87, and .60, respectively (Desoete, Roeyers and Buysse, 2001).

The adaptation of the inventory to Turkish has been carried out by the researcher (Özsoy, 2007). The reliability of the inventory restudied in the adaptation process. The inventory applied 92 students and Cronbach α's of MSA-TR were .71 for declarative knowledge, .70 for procedural knowledge, and .79 for conditional knowledge. For prediction, planning, monitoring, and evaluation Cronbach α's were .73, .78, .80, and .76 respectively. We have resorted to the method test-retest in reliability study due to the scope and quality of the inventory. The inventory has been applied to 45 students two times at an eight weeks' interval and the consistency between this resting results have been analyzed. The correlation value between the two application has been found to be .85 (p<.05).

Procedure

Since the activities are supposed to be carried out by the classroom teachers, we have felt a need to inform the teacher in the treatment group about several issues. Before the study, the teacher has been provided with a totally eight hour oral instruction over two weeks. During this instruction process, treatment group's teacher informed about metacognition, metacognitive instruction, aims of present study, study process, activities will be used in the lessons and her roles during the study. By this instruction, a teacher guide file including information given in the instruction, activity plans, and problems will be used in the activities.

Metacognitive strategy instruction using problem solving activities. Following the implementation of pre-tests, an instruction process called 'metacognitive strategy instruction using problem solving activities' has been carried out so as to develop the metacognitive strategy of students in the treatment group. The purpose of instruction of metacognitive strategy through problem solving activities is to develop students' metacognitive skills practically during problem solving activities. For this study, we preferred to apply strategy instruction together with problem-based instruction, one of the instructional practices of constructivist learning theory. This method was used in previous studies in order to develop metacognitive skills and yielded successful outcomes (Wilburne, 1997; Goldberg and Bush, 2003). The fact that this method, found appropriate theoretically, is supported by previous studies is the primary factor in our choosing it. The researcher planned all the activities carried out in treatment group.

Before starting the application activities, preparatory lessons, 80 minutes at total as (40′+40′), have been carried out in order to inform students generally about metacognition. During preparatory classes, students were provided with information about metacognition in accordance with their levels. Also, the students were given

Metacognitive Problem Solving Table during these classes. Then, they were asked to act in accordance with the steps specified in this table while working on problem solving activities. An extended version of the table was hung on notice board of the class in order to provide reinforcement.

With the aim of using in metacognitive problem solving activities, the researcher has prepared problems compatible with the students' levels in accordance with National Primary School Curriculum (MEB, 2004). Throughout the application, each of these problems has been introduced to the students in the form of work-sheets. These work-sheets also include metacognitive strategy required to be used by the students in the form of check-lists. The students have been asked to proceed in accordance with the stages included in these control-lists and to fill them upon completing each stage. The role of the teacher during these activities is to supervise the operation of the activities and guide the students by asking questions which will make the process proceed properly and lead the students to thinking. While the students are busy with the problems in work-sheets during problem solving activities, the teacher has monitored them and asked questions when necessary such as '*What did you think when you first read the problem?*', '*Did you read the problem enough to understand it?*', '*Do you think you have understand the problem?*', '*Tell me what you have in your mind?*'. '*What will you do now?*', '*Will this work for the solution?*', '*Do you think you can solve this problem?*' in order to trigger the metacognitive thinking of the students. The reasons behind these questions addressed with the aim of arouse the students' opinions about themselves and the process is mainly to encourage students to ask questions themselves. Throughout the application studies lasting a total of nine weeks (19 lessons), the students have been made to deal with 23 word problems.

During nine-week (19 Class time) application, the students were made to work on 23 problems. During metacognitive problem solving activities, the following method was followed under the guidance of the teacher:

- Process of the activity: The students are reminded to study by taking into account the stages in Problem-Monitoring Table and worksheets.
- When the students are thought to be ready for the activity, they are provided with worksheets.
- They are asked to read the problem without doing something else. (Several times- until they believe that they have understood.)
- They are asked to carry on the study in accordance with the stages contained on the edges of worksheet. This is repeated during the process if necessary.
- They are asked to write about their opinion on worksheet as much as possible.
- While studying, students are monitored and addressed questions which will encourage them to think. The most important part is to encourage them to think about themselves.
- When most of the students have completed studying, several students are asked to share the way through which they have solved the problem. During this part, the students are especially encouraged to tell about their own thinking processes. (Why did you so? / Why did you think so? / Could you

have solved the problem in a different way?). One should not fail to remember that it will play an important role in their development of metacognitive skills to share their opinions – both to express their own thinking and monitor other students' thinking processes.

- At the end of study, the students are asked to evaluate themselves. The students are made to assess their own thinking skills.
- The students are asked to write their opinions regarding the study on a study diary.
- Worksheets are collected at the end of each problem. They are examined by the researcher and teacher, and students' development is monitored. Advices on student development are written on these sheets and they are given back to students. Here, the purpose is to make them monitor their own development.

Treatment integrity. We resorted to the reliability of the application in order to receive information about to what extent the teacher had complied with the instruction carried out in the experimental group. With this purpose in mind, we used a "Teacher Observation Form" to use for collecting the data regarding the reliability of the application. The observation form includes the acts expected from teacher during the instruction. The instruction carried out by the teacher was observed by the researchers and an assistant observer by turns and these observations were recorded on observation form. The observations concluded that the teacher of treatment group had carried out the applications expected from herself at a 93.3 percentage (mean of two observers). It was determined from the observations in control group that the teacher had displayed these behaviours only at an average of 18 percent.

Control condition. However, no instruction planning has been made in the control group during the application stage of the study and the existing normal process has been allowed to go unaffected. But in order to define the process in the control group as well and to determine how different it is from the experimental group, the students in the control group have been made to solve the problems used in the experimental group in their ways. The observations in control group indicated that the teacher generally presented the problem to students, gave time for solution and then solved the problem on board and asked the students to control their solutions. Observations carried out in control group showed that the teacher did not use any other methods apart from this.

Following the nine-week application, the students have been exposed to the PSAT and MSA-TR as post-tests. And the results obtained have been analyzed in order to seek for answers for the study problems. During the analysis of obtained data, the analysis of variance (ANOVA) has been used in order to find out whether the experimental operation has proven effective or not with the significance level of .05. Also *Cohen's f* (Cohen, 1988) has been used to calculate the effect size.

Results

Metacognitive knowledge and skills

The mean scores of students regarding the pre-test and post-test obtained in the MSA-TR and the standard deviation values have been presented in Table 3.

Table 3 Pre-test and post-test mean scores of MSA-TR

	Group	N	M	SD
Pre-test	Experimental	24	118.33	47.725
	Control	23	115.52	47.351
Post-test	Experimental	24	156.54	55.448
	Control	23	115.57	49.788

As can be seen in Table 3 while the mean scores obtained in the MSA-TR by the students in the treatment group who have been exposed to metacognitive instruction through metacognitive problem solving activities was 118.33 before the treatment, this increased to 156.54 following the experiment. The same mean scores of the students in the control group are 115.52 and 115.57 respectively. Therefore, there has been an increase in metacognitive knowledge and skills of students in the treatment group, the students in the control group have not experienced such a change in the same skill.

The results of ANOVA conducted in order to determine whether there has been a significant difference between the metacognitive knowledge and skills of the students in the treatment and control group when a comparison is made between before and after the experiment have been presented in Table 4.

Table 4 ANOVA results for the MSA-TR

Source of variance	Sum of squares	df	Mean square	F	p
Between subjects	221765.809	46			
Group (Experimental/Control)	11259.583	1	8553.394	23.389	.000
Error	210506.226	45	365.699		
Within subjects	33601.809	47			
pretest-posttest	8592.415	1	8592.415	23.496	.000
Group*Test	8553.394	1	8553.394	23.389	.000
Error	16456.457	45	365.699		
Total	255367.618	93			

The results showed that the metacognitive strategy instruction in the treatment group have led to a significant difference [$F_{(1,45)}=23.389$, $p<.05$] between the treatment and control group in terms of the level of metacognitive knowledge and skills. The obtained results indicate that in the scores regarding the MSA-TR, the metacognitive problem solving activities, which have enabled a further advance when compared to level before the experiment, have proven more effective than the group that have not been exposed to the instruction of metacognitive strategy in terms of the development of metacognitive skills. Also effect size calculation results show that the treatment has a large effect (f=.446).

Mathematical problem solving achievement

The mean scores of students regarding the pre-testing and post-testing obtained in the MPSAT and the standard deviation values have been presented in Table 5.

Table 5 Pre-test and post-test mean scores of MPSAT

	Group	N	M	SD
Pre-test	Experimental	24	25.00	12.07
	Control	23	29.13	11.64
Post-test	Experimental	24	46.46	9.03
	Control	23	27.83	9.63

As can be seen in Table 5, while the mean score obtained in the MPSAT by the students in the treatment group who have been exposed to metacognitive instruction through metacognitive problem solving activities was 25.00 before the experiment, this increased to 46.46 following the experiment. The same average points of the students in the control group are 29.13 and 27.83 respectively. Therefore, there has been an increase in problem solving achievement of students in the treatment group; the students in the control group have not experienced such a change in the same skill.

The results conducted in order to determine whether there has been a significant difference between the mathematical problem solving achievement level of the students in the experimental and control group when a comparison is made between before and after the experiment have been presented in Table 6.

Table 6 ANOVA results for the MPSAT

Source of variance	Sum of squares	df	Mean square	F	p
Between subjects	7365.425	46			
Group (Experimental/Control)	1234.968	1	1234.968	9.065	.004
Error	6130.457	45	136.232		
Within subjects	9545.352	47			
pretest-posttest	2385.246	1	2385.246	26.069	.000
Group*Test	3042.692	1	3042.692	33.254	.000
Error	4117.414	45	91.498		
Total	16910.777	93			

The results showed that the instruction of metacognition strategy in the treatment group have led to a significant difference [$F_{(1,45)}$=33.254, p<.05] between the treatment and control group in terms of the level of mathematical problem solving achievement. The obtained results indicate that in the scores regarding the MPSAT, the metacognitive problem solving activities, which have enabled a further advance when compared to level before the experiment, have proven more effective than the group that have not been exposed to the instruction of metacognitive strategy in terms of the development of problem solving achievement. The effect size Cohen's *f* (Cohen, 1988) of metacognitive strategy instruction on mathematical problem solving achievement also calculated. Results show that the treatment has a large effect (*f*=.484).

According to the results of present study there has been an increase in both metacognitive and problem solving achievement level of the students in the treatment group. However, there is not such an increase in the control group. Considering these results, it can be concluded that the metacognitive strategy instruction lead to an increase in problem solving achievement.

Discussion

In this study, we have implemented an instruction process intended to develop metacognitive strategy in fifth grade students from the primary school and analyzed whether there has been an advance on problem solving achievement following the instruction. With this objective in mind, the problem of the study has been expressed as '*Does metacognitive strategy instruction in fifth grade of the primary school have an impact on problem solving achievement?*'. As a result of the present study, at the end of the experimental process there has been observed a significant difference between the groups who have been exposed to the instruction of metacognitive strategy and those who have not been, in terms of metacognitive knowledge and skills. This conclusion supports the former studies (El-hindi, 1996; Wilburne, 1997; Marge, 2001; Goldberg and Bush, 2003) which maintain that there is an attempt to develop metacognitive skills in students at different and similar levels, and metacognitive skills can be increased through instruction. In support of the results of former studies, the results of this study suggest that metacognitive skills can be developed through instruction. Also we have observed that there is a meaningful difference between the students in the experimental group and control group in terms of the problem solving achievement level. This finding proves that the instruction of metacognitive strategy has a distinctive impact on increasing the problem solving achievement levels of students supporting the studies conducted by Lucangeli, Galdersi and Cornoldi (1995). Considering the outcomes of the study, as an answer for the study problem, it can be concluded that, the instruction of metacognitive strategy lead to an increase in problem solving achievement level. This outcome of the study supports the previous studies (Whimbley and Lochhead, 1986; Swanson, 1990; Lucangeli and Cornoldi, 1997; Wilburne, 1997; Gourgey, 1998; Desoete, Roeyers and Buysse, 2001; Marge, 2001; Kramarski, Mevarech and Liberman, 2001; Goldberg and Bush, 2003) in which the correlation between problem solving and metacognitive skills is studied.

The results revealed that, there was an increase in problem solving skills of the students who have been exposed to the instruction of metacognitive strategy. For this reason, metacognition can be used as a useful tool in order to develop the problem solving skills which is included among the primary objectives of primary school curricula and which plays an important role in the academic development of students. Accordingly it is suggested that, all instruction processes should include the instruction of metacognitive skills. Results of the study also showed that supporting the students with questions regarding their own thinking processes during problem solving activities, triggers metacognitive behaviours. For this reason, an application towards this aim during problem solving activities in schools will be useful for students. Present study supported that in Math courses metacognitive strategy instruction improves problem solving achievement. For further studies, investigating the effect of metacognitive strategy instruction on student achievement in courses such as arts and social sciences is suggested.

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On the development and measurement of spatial ability

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ABSTRACT

The importance of spatial ability in learning different school subjects and being successful at certain jobs has been recognized globally. The vast majority of the studies on the topic have focused on the nature of the phenomenon, the factors that affect its development), and the difference between males and females on spatial ability. However, still there is a need to conduct research studies to have a better understanding of the construct, its relations with other abilities, and the ways to foster its development. By providing a literature review, this study addresses those issues and summarizes different ways of measuring spatial ability and fostering its development to suggest study directions to future researchers.

Keywords: *spatial ability, gender differences*

Introduction

As a collection of cognitive skills that enable one interact with his environment, spatial ability has been an area of study for decades (Hegarty and Miller, 2005). Understanding the nature of the construct is crucial to increase the success rate in mathematics and science courses, which are among the most important subjects, especially to be successful at technical jobs in today's competitive work environment (Halpern, 2000; Siemankowski and McKnight, 1971). Many items asked in high-stake tests, not only country-wide selection assessments but also international comparative assessments, such as Trends in Mathematics and Science Study (TIMSS) and Program for International Student Assessment (PISA), have a common construct: spatial ability.

What is Spatial Ability?

According to Linn and Petersen (1985) spatial ability refers to "skill in representing, transforming, generating, and recalling symbolic, non-linguistic information" (p.1482).

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Lohman (1993) defined the visual ability as "the ability to generate, retain, retrieve, and transform well-structured visual images" (p.3). Oliveira (2004) draws attention to the fact that spatial ability is included in most of the multiple aptitude batteries; however, there are contradictions in the spatial domain literature, which makes the topic difficult to understand. She summarized those contradictions as follows:

1. While there are same descriptions under different names, there are identical names for different components of spatial ability.
2. Number of underlying components/factors of spatial ability varies by researchers - ranging from two to ten.
3. Factor names vary across authors and even within a work of the same author.
4. Confusion exists among the researchers regarding the names and contents of a variety of spatial ability tests.

Based on their literature review on spatial ability, Cooper and Mumaw (1985) concluded that "… literature is quite clear in showing that a broadly defined spatial factor exists independently of verbal and quantitative factors" (p.71). Although there is an agreement between the researchers that spatial ability is an important component of the intellectual ability, there is no consensus on the nature of the phenomenon. As Linn and Petersen (1985) indicated that spatial ability is not a unitary construct, but it is combination of sub-skills such as using maps, solving geometry questions, and recognizing two dimensional representation of three-dimensional objects. Carroll (1993) stated that "considerable confusion exists about the identification of factors in this domain tests do not always load consistently on distinct factors, or they load rather indiscriminately on a number of factors" (p.308). Therefore, different kinds of spatial abilities have been proposed based on factor analytic studies.

The factor structure of spatial ability has been an area of study since the mid-1940s; however, those studies did not provide a clear picture of the underlying factors of the subject. An extensive study by McGee (1979a) reviews the literature and shows that the reason for inconsistency and confusion concerning the structure of spatial ability is investigators' inconsistent naming of the factors. McGee (1979a) concludes that there are two main factors: *Spatial Visualization* (Vz) and *Spatial Orientation* (SO). Vz is the ability to imagine manipulating, rotating, twisting, or inverting objects without reference to one's self. This ability is measured by complex tests, such as Paper Folding (Ekstrom, French, Harman, and Dermen, 1976, as reported in Snow and Lohman, 1979). McGee explained the other important dimension, SO, elsewhere (McGee, 1979b) as "the comprehension of the agreement of elements within a visual stimulus pattern and the aptitude to remain unconfused by the changing orientation in which a spatial configuration may be presented" (p.893). In short, *Spatial Orientation* is perceived as one's ability to imagine the appearance of an object from different perspectives.

In another review, Lohman (1988) argues that there are three major spatial ability factors: *Spatial Visualization* (Vz), *Spatial Orientation* (SO), and *Speeded Rotation* (SR). He explains that Vz is the most general factor; however, it is difficult to identify because the tests that define it usually have high loadings on the *general intelligence,* or overall mental ability. One important characteristic of the tests that define the Vz is their complexity. Some require rotation, reflection, or folding complex figures, others require combining different figures, yet some others require multiple transformations. When defining the SO, Lohman (1988) agrees with McGee and adds that it is difficult to separate SO from Vz because both of these factors require considerable reasoning skill and subjects may solve items by mentally rotating them rather than moving an image of the self to the desired perspective. Lohman (1988) believes that SR factor is defined by the tests in which subjects are required to determine whether a given stimulus is a rotated version of a two dimensional target (i.e., game card) or is a rotated and reflected version of it. A quick answer is expected from the examinees when taking those kinds of tests.

As Hagarty and Waller (2005) stated, the most comprehensive review of factor analytic studies of spatial ability was conducted by John Carroll in 1993. Carroll (1993) analyzed more than 140 datasets and detected five major clusters: *Visualization* (Vz), *Spatial Relations* (SR), *Closure Speed* (CS), *Flexibility of Closure* (CF), and *Perceptual Speed* (P).

Carroll's (1993) definition of Vz factor does not differ from than that of other researchers cited above. *Spatial Relations* factor can be considered as another name for the *Speeded Rotation* factor defined by Lohman (1988) for three dimensional objects. CS factor concerns individual differences in ability to access spatial representations in long-term memory when incomplete or obscured cues to those representations are presented. The subjects are not told what to look for in a given representation. CF factor involves finding hidden patterns or figures in a bigger complex pattern when the subjects are informed about what to look for. CF factor is sometimes called *Field Independence* or *Disembedding* by other researchers (Velez, Silver, and Tremaine, 2005). Although Carroll (1993) informs that the CF factor exists, he admits the fact that "the psychometric evidence for the factor is somewhat ambiguous" (p. 338). P factor is characterized by the speed in finding a given configuration in a mess of distracting material. The task may include comparing pairs of items, locating a unique item in a group of identical items, or locating a visual pattern in an extended visual field. The factors detected by Carroll (1993) are shown in Figure 1.

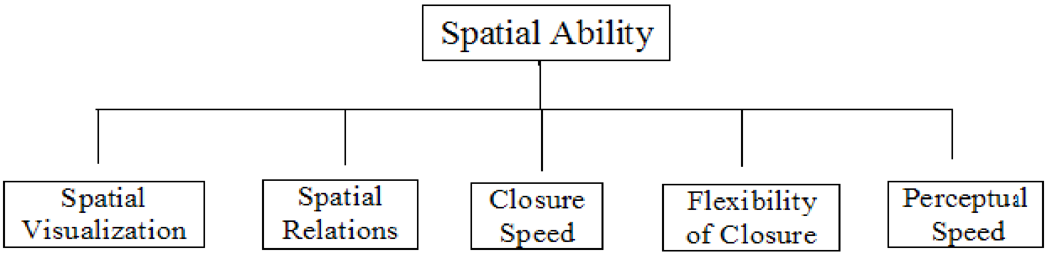


Figure 1 *Major factors of spatial ability based on Carroll's (1993) analysis*

Factor analytic studies on spatial ability have two main shortcomings. First, they do not provide the same results (i.e. detect the same underlying factors), which may lead to incorrect conclusions and confusion. To illustrate, while some of the studies clearly identify an SO factor, a comprehensive analysis of previous data sets by Carroll (1993) does not suggest such a factor. Second, those studies neglect dynamic spatial abilities and environmental abilities, which are considered as very important components of spatial ability domain (Hegarty and Waller, 2005).

Dynamic Spatial Ability (DSA) or *Spatiomeporal Ability* (SA) refers to judgments regarding a moving stimulus (Halpern, 2000). DSA is generally measured in the context of computerized tests (Colom, Contreas, Shih and Santacreu, 2003). The relative arrival time (which requires individuals to indicate which of the two moving objects will arrive first at a given target) and intercept judgment tasks are the markers of DSA (Law, Pallegrino and Hunt, 1993). *Environmental Ability* (EA) requires integrating spatial information about natural and artificial objects and surfaces in an individual's surroundings. These abilities are considered essential for way-finding and navigation (Allen, 1999; Bell and Saucier, 2004).

It can be concluded that spatial ability factors include the ones that Carroll (1993) suggests in addition to SO, DSA, and EA. As Hagerty and Waller (2005) argues, Carroll's (1993) failure in finding a separate SO factor does not mean that such a factor does not exist. It is possible that this ability has been poorly assessed. Theoretically, the critical distinction between Vz and SO is that Vz involves imagining the object's movement whereas SO involves imagining the change in one's perspective. Although there is a strong evidence regarding the existence of DSA and EA abilities to solve most of the spatial problems we encounter in our daily lives, some researchers noted that the mainstream literature ignore this fact (Allen, 1999; Allen, 2003; Bell and Saucier, 2004). To illustrate, environmental abilities are needed to find one's way between two known or unknown points. A comprehensive model of general spatial ability, including those overlooked components, is provided in Figure 2.

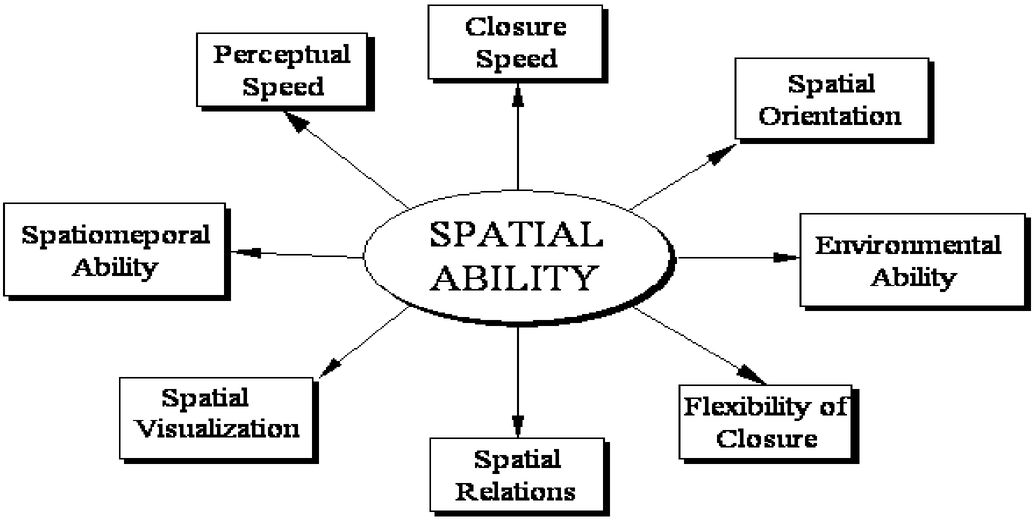
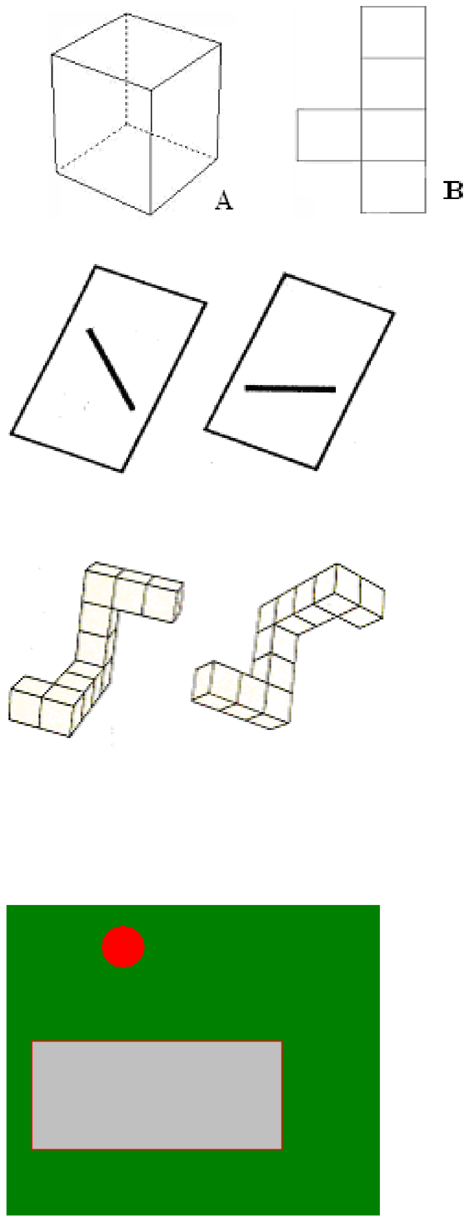


Figure 2 *Major factors of spatial ability.*

The debate on the nature and types of the spatial ability is still continuing. In a recent study, Allen (2003) groups spatial ability into three functional families: *object identification* (answering the "What is it?" question), *object localization* (answering the "Where is it?" question), and *traveller orientation* (answering the "Where am I?" question). According to the researcher, the "What is it?" family of abilities involves a stationary observer and stationary (usually movable or manipulable) objects; the "Where is it?" family involves the context of situations including either a stationary or mobile observer and mobile (mostly animate) objects; and the “Where am I?” family involves a mobile observer and a stationary world of environmental objects and surfaces. It seems that his work actually re-groups the factors in *Figure 2* under bigger clusters. *Figure 3* includes item samples for some of the major components of spatial ability.



Spatial Visualization
Is Figure B part of Figure A?

Spatial Orientation [b]
Align a rod within these frames so that the rod is vertical.

Spatial Relations [1]
Is this pair of figures same or not?

Spatiotemporal Abilities

A falling red ball is obscured by a shaded rectangular area on the computer screen. Press any key when you expect it to be visible on other side of the shaded area.

Figure 3 *Examples of spatial ability test items.*

Development of Spatial Ability

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[b] Adapted from Halpern, 2000

Development of spatial cognition which entails the ability to mentally represent spatial relations and to anticipate the course and outcome of transformations applied to those relations has long attracted the interest of behavioural scientists (Rosser, 1995). Writings of Piaget has guided the research on the developmental aspect of the phenomenon. His work suggested that children's spatial ability does not reach an adult level before age twelve (Piaget and Inhelder, 1967). Piaget and Inhelder (1967) defined two types of spatial ability when a child interacts with his/her environment. *Perceptual Spatial Ability*, the ability to perceive the spatial relationships between objects; and *Conceptual Spatial Ability*, the ability to build and manipulate a mental model of the environment. According to those researchers, children progress through three stages in the development of their cognitive spatial ability: preoperational stage, concrete operational stage, and formal operational stage.

Piaget and Inhelder (1967) indicated that children younger than six years old are in the *preoperational* stage of cognitive development. The internal model of children in this stage is egocentric; that is, they locate objects in their environment with respect to themselves. They understand limited topological spatial relationships, such as separation, proximity, and open/closed. The second stage is the *concrete operational* stage, which occurs when children are between seven to nine years old. In this stage they develop a cognitive map with a fixed frame of reference, which allows them to imagine a view and orientation outside their body. Children develop an understanding of more complex topological relations using an external frame of reference, such as order and enclosure, and they begin to develop projective relations, like before/behind, and left/right. The last stage of cognitive development in childhood is the *formal operational* stage, which begins around the age of 11. In this stage, children develop a coordinate frame of reference, where individual routes blend into a network of locations in fixed positions relative to each other. They develop an understanding of Euclidean spatial relations, such as estimating straight-line relative distances, and proportional reduction of scale (Piaget and Inhelder, 1967).

On the other hand, Huttenlocher and Newcombe (2000) suggest that spatial understanding develops earlier than proposed in Piaget's work, and believe that the stages of spatial development can be summarized as follows:

- Infants at the age of six months are able to use dead reckoning skills (e.g. keeping track of direction of a moving item by integrating distance traveled with changes in motion and heading) to understand the location of objects around them. This is an inborn ability to understand distances and people use it to navigate.
- Babies at 12 months are able to understand distance in a way that helps them find hidden stimuli.
- By 18 months, they are able to understand and navigate simple routes.
- Children are able to use distance information from landmarks to define locations, which seems to be related to the maturation of the brain, by they are two years old. Piaget had contended that this ability did not develop until ages nine or ten.
- They are able to use simple maps and models at three years old.
- Children continue to grow in spatial understanding and complete their mental development in spatial learning by the time they are nine or ten provided that

they are encouraged to use/play with maps and tools (Huttenlocher and Newcombe, 2000).

As indicated above, whereas there is a consensus on the idea that children's spatial ability is not as high as adolescents', there is a lack of agreement among the scientists about the process and steps of spatial development. Furthermore, research indicates that the development pattern of spatial ability for boys and girls are somewhat different from each other (Maccoby and Jacklin, 1974; Cohen, 1977; Glea and Kimura, 1993). The next part of the paper will look at this topic along with other issues regarding gender differences in spatial ability.

Gender Differences in Spatial Ability

Although it is accepted that there are differences between males and females in their spatial abilities, the nature and magnitude of that difference is another topic on which researchers disagree (Maccoby and Jacklin, 1974; Linn and Petersen, 1985; Voyer et al., 1995). Since most of the spatial ability tasks correlate strongly, researchers grouped those tasks under categories when studying the gender issue (Linn and Petersen, 1985; Voyer, et al., 1995). Those categories and the tasks that constitute them will be discussed below. Note that the components that are commonly accepted as showing reliable gender differences will be examined first. In addition, the size of any sex difference in spatial performance is reported using the statistical effect size, *d* (the mean standardized difference between scores of two groups; males and females) which can be calculated as follows:

$$d = \frac{\mu(big) - \mu(small)}{\sigma_{pooled}} \quad \text{where}$$

$\mu_{(big)}$ = bigger mean;
$\mu_{(small)}$ = smaller mean;
$\sigma_{(pooled)}$ = the square root of the average of the squared standard deviations.

An effect size of 1.0 describes a sex difference of 1 pooled standard deviation between the means. According to Cohen (1977), an effect size over .80 represents a 'large' effect.

Mental Rotation (MR)

Before going any further, it is necessary to remind that researchers have given different names to same (or very similar) components of spatial ability. When the topic is gender difference, many researchers (Kimura, 1999; Linn and Petersen, 1985; Voyer, et al., 1995) used *Mental Rotation* (MR) having a very close meaning to Carroll's Spatial Relations (SR) factors. The difference is that MR includes rotating a two or three dimensional object or figure, whereas SR requires imagination of an object in two or three dimensional space in relation to another object (Aszalos and Bako, 2004).

Vanderburg and Kuse's (1978) version of Mental Rotations Test (MRT), which is originally created by Shepard and Metzler (1971), is the most commonly used test to measure MR ability. This test involves questions that require subjects to decide whether novel three-dimensional objects are the same as a sample object regardless of their orientation. Results of meta-analyses (Linn and Petersen, 1985; Voyer, et al. 1995) showed that, although the amount of difference varies by the age of the group taking MR tests, males tend to outperform females on MR at any age starting with age 10, at which the earliest measurement of MR was possible. Voyer et al. (1995) calculated effect sizes between $d=.56$ ($p<.05$) and $d = .019$ (varies by tests). A study by Levine, Huttenlocher, Taylor and Langrock (1999) shows that there is a significant male advantage on mental rotation task by the age of 4.5.

While the object used in MR tasks differs as a result of a number of factors, such as complexity and dimensionality, overall task difficulty seems to be the primary determinant of the size of the difference. For instance, tasks including three-dimensional stimuli are commonly reported as showing a larger sex difference than the ones including two-dimensional stimuli (Linn and Petersen, 1985).

Spatial Perception

Linn and Petersen (1985) and Voyer and his colleagues (1995) perceive this component as the ability to determine spatial relationships with respect to the orientation of one’s own body. A very similar definition is given for *Spatial Orientation* by McGee (1979b) as mentioned above. Rod and Frame Test (RFT) (shown in Table 1) and Piaget and Inhelder’s (1956) Water Level Test, which involves the orientation of water line in a tilted glass, are the most commonly used tests to measure *Spatial Perception* skill. Voyer et al. (1995) reported male advantage with an effect size of .42 for the first test and .48 for the second one.

Kimura (1999) argues that these tests also measure *Field Independence* or *Flexibility of Closure* (CF) skill. He explains that the tilted frame and tilted glass serve as distracters from vertical and horizontal respectively. Individuals who can disregard these distractions perform better than the others. Voyer et al. (1995) state that the earliest age at which gender differences reported is 7 for the RFT, and 9 for the Water Level Test; on the other hand, Linn and Petersen (1985) point out that at age 4 girls outperform boys, but starting from age 5 boys get better scores than girls, and the difference gets statistically different at age 11.

Spatial Visualization

Tasks that have been grouped by Linn and Petersen (1985) and Voyer et al. (1995) as spatial visualization tests also show male advantage. Yet, the difference between males and females on those tests are much smaller and less reliable than those found in the *Multiple Rotation* and *Spatial Perception* groups. Among the most employed tests to measure spatial visualization tasks are Paper Form Board, which requires individuals to detect what an unfolded shape would look like when folded, and the Identical Blocks Test, in which participants should decide which block among a number of alternatives is the same as a sample block, given a variety of identifying features such as colours and numbers on the faces of the blocks. Voyer et al. (1995) inform that the difference before age 18 is not significant; however, the difference becomes significant ($p<.05$) with an effect size of .23 when the participants are over 18 years old.

Other Findings on Gender Difference

Literature includes studies focusing on gender differences in the other spatial ability domains as well, such as *Dynamic Spatial Abilities* (DSA) and *Environmental Abilities* (EA); however, the number of studies on DSA is not enough to allow reliable effect size estimates (Halpern and Collaer, 2005). Law, Pellegrino, and Hunt (1993) conducted an experiment to examine the gender difference in relative velocity and distance judgment tasks. Subjects observed two dynamic objects moving in different paths with different velocity values on the computer screen and asked to identify which object was moving faster. Tasks involving judgments about the speed or anticipated position of moving targets resulted in higher scores for males. Tests that assessed navigational (way-finding) ability by different tasks, such as using maps and three-dimensional environments, also found male superiority. To illustrate, Glea and Kimura (1993) concluded that, when learning a novel route through a map of a town, males showed faster learning and made fewer errors.

The literature has well established that males perform better than females on spatial tasks. Linn and Petersen (1985) suggest that females use less effective strategies than males, which result in a better male performance on spatial tasks. For instance, they observed that females tend to reflect more caution, double check their answers, and take more time when they are to answer test items. Linn and Petersen (1985) also noted that females find spatial tasks more difficult than males do.

There are many competing explanations for gender difference, but it is possible to put them into two main groups: (a) *biological factors*, (b) *socio-cultural factors*.

Biological Factors

Majority of the research explaining gender differences in terms of biological factors focuses on two main areas: hormones and brain maturation. Studies with hormonal abnormalities show that gonadal hormone levels are related to the development of spatial skills (Levy and Heller, 1992). For instance, females who have high androgen levels during prenatal development and early ages have higher spatial ability than others (Hampson, Rovelt and Altman, 1998), and males who have low androgen level at early ages have low spatial ability than normal males (Hier and Crowley, 1982; cited in Levine et al., 1999). Prenatal exposure to androgens is thought to be an important factor in the development of spatial ability.

The human brain is divided into two hemispheres; the left hemisphere underlies language and verbal skills and the right hemisphere underlies visual-spatial skills. It has been known for decades that the right hemisphere in fatal males is bigger and develops earlier than that of females (de Lacoste, Hovarth and Woodward, 1991), which is hypothesized to be related to the spatial skill advantage in males (Levine et al., 1999). In addition, Pakkenberg and Gundersen (1997) inform that males have 16% more neocortical neurons than females, which may result in more synaptic connections and contribute to cognitive differences.

Socio-cultural Environment

Socio-cultural environment includes issues like play, gender roles, social and parental expectations, and educational experiences that affect the development of a child's abilities. Voyer, Nolan, and Voyer (2000) observe that while most of the male-typical activities involve a high spatial content, female-typical activities do not. Childhood experiences are thought to have influence on the development of spatial ability (Saucier, McCreary, and Saxberg, 2002).

While gender differences in toy play appears at a very young age, it is not clear exactly when the difference in toy preferences appears. Some studies suggest that, as early as age 3, children prefer to play with toys deemed appropriate for their own gender (Green, Bigler, and Catherwood, 2004). On the other hand, other researchers, such as Jackllin, Mackoby, and Dick (1973), found evidence that gender differences in toy preferences exist in 1-year-old children. Most of the time boys play with toy vehicles and blocks, which involve spatial manipulations, while girls play with stuffed animals and dolls, which help the development of social skills (Etaugh and Liss, 1992; Levine et al. 1999; Voyer et al, 1995). It has been reported that preschool boys spend more time with their teachers than girls, and they play games with construction sets, toy vehicles, blocks, and legos; however, girls spend most of their time in dramatic play area and interact socially (i.e., verbally). This is also the case when those children spend time at home either with their parents or caregivers (Levine et al., 1999).

According to the social learning theory, operant conditioning of gender roles can play roles on toy preferences. The consequence of behaviour affects the likelihood of the recurrence of that behaviour: while favourable consequences increase the tendency to repeat the behaviour, adverse consequences decrease it (Mazur, 2005). Lytton and Romney (1991) reviewed more than 170 studies on parents' behaviour towards children and found that parents encourage girl-typical toy (e.g., with dolls) more in girls and boy-typical toys (e.g., with blocks) more in boys. After reviewing the literature on child toy preferences, Lippa (2002) concludes that "parents engage in *gender policing* when their children engage in cross-sex activities. Fathers tend to police more than mothers, and everyone polices boys more than girls" (p. 137). In this case, it could be expected that boys will have higher spatial ability than girls since they are encouraged to play with toys that require more spatial skills.

Besides the toy preference, typical play activities for boys are generally rough sports, such as football and ice-hockey requiring more spatial skills (especially targeting skill) than others like swimming and jogging (Kimura, 1999; Voyer et al., 2000). It is important to state that toy and play preferences are not thought to be only as a function of social experiences. A group of researchers propose that innate biological differences and the brain development also have influence on those issues (Alexander and Hines, 2002, cited in Green et al., 2004). Based on the previous studies on toy preferences and game types during early childhood, it is logical to claim that boys have more opportunity to develop their spatial ability than girls, which may –at least partially- help explaining the reason for the gender difference in spatial ability.

Another socio-cultural factor that may lead to gender differences in spatial ability is the differences in occupational choices. Some occupations requiring spatial ability are mostly preferred by males (e.g., pilot, engineer, surgeon, etc.) (Halpern, 2000). This may be caused by experience, social pressure, and educational opportunities. For instance, being canalized to play with certain kinds of toys and pressure from parents and teachers may result in an increase in spatial ability. Guay and McDaniel (1977) reported that “...among elementary school children, high mathematics achievers have greater spatial ability than low mathematics achievers.” (p.214). Moreover, it is reported that there are gender differences favouring girls in verbal abilities and favouring boys in mathematical abilities (Maccoby and Jacklin, 1974).

It has been suggested that the nature of advanced topics in mathematics (geometry, topology, trigonometry, etc.) require spatial skills (Halpern, 2000). Similarly, Skolnick, Langbort, and Day (1982) argue that spatial ability plays an important role in children’s understanding in mathematical and scientific concepts. Siemankowski and McKnight (1971) give examples that might be the reason for high correlation between spatial ability and success in science classes:

> Science students are constantly subjected to diagrams, usually of two dimensional representations of three dimensional models ... The need for three-dimensional conceptualization is necessary for the comprehension of wave energy transmission, chemical bonding, fields of force, structure of the atom, x-ray diffraction patterns, DNA, cell division, and countless other concepts and phenomena found in every branch of science (p. 56).

In general, boys have a higher spatial ability than girls which may be caused by biological and/or environmental factors. As a result of that difference, some occupations closely related to spatial ability have been male-dominated.

There is evidence that the difference between males and females in their spatial ability is changing. Feingold (1988) proposed that the gap between males and females in spatial ability has decreased as a result of an increase in spatial experience of females. However, Voyer et al. (1995) believes that, although the difference in mental rotation tends to increase, the difference in spatial perception tends to decrease for individuals born recently, which makes one think that various spatial tasks may be differentially sensitive to the effects of experience.

One of the increasingly popular ways to interpret gender differences in spatial performance is to consider that they arise from an interaction of biological and socio-cultural factors. Sherman’s (1978) “bent twig” theory is a good example of that approach. This theory says that when choosing an activity, one of the many factors involved is an innate predisposition for the abilities required by that activity. This means that boys might tend to do some activities (i.e., playing with blocks) because of their inborn predisposition for spatial abilities. From this perspective we can argue that “boys generally have good spatial abilities from an early age and this guides their choice of activities, which in turn contributes to an increase in the magnitude of gender differences” (Voyer et al., 2000, pp.893). This explanation seems to help us understand the nature of the difference in spatial ability.

There have been many studies investigating the ways to improve spatial ability of individuals. For instance, Leng and Shaw’s (1991) found that similar neural firings patterns occur when listening to music and performing spatial tasks; Rauscher, Shaw and Ky (1993) hypothesized that listening to certain types of complex music warms-up neural transmitters inside the cerebral cortex (region of the brain that is responsible for cognitive functions) and thereby improve spatial performance. Rauscher et al.’s (1993) experiments showed that listening to the first ten minutes of the Mozart's Sonata *K.448* resulted in significantly higher scores on college students' spatial-temporal ability (i.e., combining separate elements of an object into a single whole) for about fifteen minutes. Hundreds of similar studies have been conducted to investigate the effects of Mozart's music on spatial ability for different age groups (mostly with college students); however, the results of those studies remain controversial. Even replication studies suggested inconsistent findings (McKelvie and Low, 2002). On the other hand, research on the effect of music training on spatial ability development of preschool children has provided consistent results that music education increase spatial performance (Rauscher, 1996). To illustrate, Rauscher et al. (1997) conducted a two-year study that examined the effect of keyboard training on spatial ability of preschool children. They had four groups of preschool children whose age ranged from 36 to 57 months: first group took piano lessons and participated in singing sessions; remaining students were assigned to one of the three groups—Singing (participated in singing sessions), Computer (took computer lessons), and No Lessons. The result of the study indicated a significant ability increase only for the first group.

Conclusion

Spatial ability and its development in males and females have attracted the attention of researchers for a long time. Yet, as literature points out, there are many studies revealing contradicting results which make it difficult to have a comprehensive understanding of the subject (Newcombe and Learhmont, 2005; Halpern, 2000; Pallegrino and Hunt, 1991; Snow and Lohman, 1985). Although the number of underlying factors of spatial ability varies from study to study, most investigations have found significant differences between males and females in most of those factors, such as *Mental Rotation*, *Spatial Relations* (Voyer et al., 1995, Linn and Petersen, 1985), and *Environmental Ability* (Glea and Kimura (1993).

As discussed in the current study spatial ability is a comprehensive construct which have an effect on one's everyday life, school achievement, and success in certain types of jobs. Efforts to comprehend the nature and development of spatial ability have led to two distinctive underlying dynamics: biological and socio-cultural factors. Examination of the factors like neural system, genes, toy preferences, teacher and parent behaviours, and job preferences, and the interactions between them, will help researchers find more efficient ways to increase spatial ability and explore better means of delivering instruction to children.

As a result, achievement gap between boys and girls on mathematics and science courses might be diminished. Along the same lines it might be possible to increase the girls' enrolment rate in currently male-dominated science, mathematics and technology related courses and departments when they go to higher education institutions.

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Book Review

How the Brain Learns Mathematics

David A. Sousa.
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How children learn mathematics has been the focus of research for many years. The research base has developed with theories from mathematics education, educational psychology and cognitive psychology (e.g. Geary, 1990; Ginsburg, 1997; Rousselle and Noel, 2007; Wright, 1994). Math educators have used this research to help guide instructional practices and to help them make sound instructional decisions. Recently, brain-imaging technology has brought the field of neuroscience into the study of teaching and learning mathematics. Imaging technologies have allowed scientists to determine which areas of the brain are active when the mind is engaged in mathematics. This technology has given researchers and educators a new piece of the learning puzzle. It is now possible to compare learning theories in mathematics to neurological analyses of how the brain physically functions while it is doing mathematics. In this book David Sousa links research and theory in mathematics teaching and learning to emerging research in neuropsychology. He reviews knowledge of the human brain's evolution and physiology, as well as current theories about teaching and learning and merges that knowledge with new information from brain imaging.

In the first two chapters of *How the Brain Learns Mathematics*, Sousa traces a genetic history of number sense using research from cognitive science and psychology. He begins with the assertion that people have an innate number sense (p.9). He cites experiments, such as infant gaze studies that suggest a basic and innate sense of number. In these gaze studies, babies are shown images of sets of two objects and sets of three objects. The babies consistently look for longer periods of time at the sets of three objects. This finding indicates that babies can detect differences in quantity at very early ages. Mathematics may be viewed as a subject learned in school but this

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research suggests that number sense may be hardwired in our brains.

Sousa also uses research on brain function to further support the notion that humans may have innate mathematics ability. Brain imaging has shown that the region of the brain that controls finger movement is the same as the region attached to counting (p.15). While Sousa concedes that it is not known if the proximity of the two brain functions is purely a coincidence, it is still interesting that finger movement and counting are such close neurological neighbors.

After developing a genetic foundation for mathematical thinking, Sousa moves to a brain imaging based explanation of memory and learning. He organizes the chapters according to three age bands; kindergarten, preadolescence and adolescence in order to highlight the differences in the developing brain and the impact of those differences on students' ability to learn mathematics. Sousa approaches the study of each of the age bands through the lens of cognitive and educational theory. He skillfully layers information from brain scans to show the parts of the brain that are active during different mathematics activities. This section of the book is particularly relevant to classroom teachers who are interested in tailoring mathematics instruction to children's cognitive and neurological development.

From an instructional perspective, Sousa emphasizes meaning based teaching for all age bands. He makes a case for meaning based instruction by drawing primarily on memory research. He advocates using mathematical reasoning and meaning based activities because new learning that is meaning based has been linked to long-term retention in memory (p.56). As an advocate for meaning based learning, Sousa argues that a topic like the division of fractions is best taught through the use of models that help students construct the meaning of the operation and the quantities. He discourages the use of tricks in teaching topics like the division of fractions. "Just invert and multiply" may help students store the procedure for the division of fractions but it is unlikely to help them connect the division of fractions to larger mathematical ideas.

Sousa also advocates that teachers attend to research on memory when planning lessons. Teachers who plan with knowledge of working memory understand that students can only hold about five or six new pieces of information in their working memory. Teachers who limit the number of objectives per lesson increase the likelihood that their students will remember more of the information in the lesson (p.201).

Sousa dedicates a chapter to recognizing and addressing mathematics difficulties. The chapter addresses environmental, neurological and other factors that may contribute to these difficulties and even disabilities. Sousa argues that a teacher's perceptions about how children should be taught and assessed can influence how a disability is perceived or diagnosed (p.164). A child who struggles with rote memorization, for example, might be diagnosed as learning disabled by an instructor who relies heavily on memory-based instruction. That same child might have strengths in problem solving and would not be diagnosed as learning disabled by a teacher who attends to problem solving over rote memorization.

Environmental and instructional settings that make a child feel anxious may also contribute to mathematics difficulties. Sousa documents some of the physiological effects of stress and anxiety on memory and cognitive function (p.172) and offers suggestions for teachers who are interested in developing mathematics learning environments that mitigate anxiety.

Sousa also explores physiological aspects of mathematics learning disabilities. The use of functional magnetic resonance images (fMRI) to diagnose and monitor learning disabilities is an emerging field in neuroscience. Scientists are using fMRI to compare the brains of children with learning disabilities to those of children who are functioning normally in school. Sousa includes images from fMRI to compare students with dyscalculia, a mathematics disability, to the brains of typically functioning children (p.181). The images suggest that the brains of students with learning disabilities are physiologically different from students who do not have learning disabilities.

Sousa draws attention to a promising new avenue for educational research. Brain imaging is potentially promising as an additional lens to define and diagnose mathematics learning disability- but the field is still new. On one hand, some researchers (e.g. Temple et al., 2003) have used brain imaging to measure differences in the brains of learning disabled and non learning disabled children and then measure the changes in the learning disabled brains as a result of instruction. On the other hand, a shortcoming of this book is that Sousa does not point out the relative newness of the use of brain imaging in diagnosing disability in children. In other fields, there is criticism of the use of brain imaging for clinical diagnoses. The American Psychological Association, for example, does not support the use of brain imaging for the clinical diagnosis of mental illness in adolescents (Council on Children Adolescents and their Families, 2005) because they argue that there are as many differences within the categories of normal and abnormal brains as there are across categories.

In the final chapters, Sousa offers many instructional suggestions and activities that teachers can use in the classroom. Some of the suggestions, such as organizing the class period to correspond with the most attentive periods for children (p. 205), correspond directly to research. A weakness of the book is that some of the suggestions for classroom practice do not seem consistent with the research. For example, Sousa suggests that students use a mnemonic to help them memorize the procedure for multiplying fractions. This suggestion is contrary to the arguments for meaning based instruction that he develops throughout the book.

In spite of its weaknesses, this book can support classroom teachers who are interested in using research-based approaches to design brain compatible instruction. The book may also appeal to a broader audience of non-educators who are interested in the popular topics of brain imaging and brain based learning. Sousa’s book is an enjoyable and informative read that makes research from mathematics education, cognitive science, psychology and neuro-psychology accessible to a broad audience.

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