INVESTIGATION OF HIGH SCHOOL STUDENTS' SPATIAL ABILITY

A THESIS SUBMITTED TO
THE DEPARTMENT OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

EMİNE BANU KAYHAN

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
SECONDARY SCIENCE AND MATHEMATICS EDUCATION

JANUARY 2005

Approval of the Graduate School of Natural and Applied Sciences

Prof.Dr. Canan ÖZGEN

Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof.Dr. Ömer GEBAN

Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Assoc.Prof.Dr.Safure BULUT

Supervisor

Examining Committee Members

Prof.Dr. Ömer GEBAN	(METU, SSME)	_____________
Assoc.Prof.Dr. Safure BULUT	(METU, SSME)	_____________
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Name, Last Name :Emine Banu Kayhan

Signature :

ABSTRACT

INVESTIGATION OF HIGH SCHOOL STUDENTS' SPATIAL ABILITY

Kayhan, Emine Banu

MS, Department of Secondary Science and Mathematics Education

Supervisor: Assoc. Prof. Dr. Safure Bulut

January 2005, 78 pages

The purposes of the study were to investigate the effect of type of high school on spatial ability, to investigate the relationships between mathematics achievement, logical thinking ability and spatial ability, and to investigate the effect of technical drawing course on the development of spatial ability.

The study was conducted in Beypazarı-Ankara with 251 9th-grade students who enrolled to general, Anatolian, foreign language, commercial vocational and industrial vocational high schools.

Two measuring instruments were utilized: Spatial Ability Test and Group Test of Logical Thinking. Spatial Ability Test, which was developed by Ekstrom, consists of card rotation, cube comparison tests measuring the spatial orientation ability and paper folding and surface development tests measuring the spatial visualization ability. The tests were translated in to Turkish by Delialioğlu, (1996). Group Test of Logical Thinking was developed by Roadrangka, Yeany, and Padilla and a Turkish version of GALT was developed by Aksu, Beberoğlu and Paykoç (1990).

In order to analyze the obtained data, one way Analysis of Variance, Pearson product moment correlation, t-test were used.

The results of the study indicated that there is no significant effect of type of high school on students' spatial abilities; there is a significant positive relationship between spatial ability and mathematics achievement; there is a significant positive relationship between spatial ability and logical thinking ability; there is a significant positive relationship between the spatial ability and technical drawing achievement; and there is a significant development in spatial abilities of the students in the technical drawing course.

Keywords: Spatial ability, spatial visualization ability, spatial orientation ability, logical thinking ability, technical drawing.

ÖZ

LİSE ÖĞRENCİLERİNİN UZAYSAL YETENEKLERİNİN İNCELENMESİ

Kayhan, Emine Banu

Yüksek Lisans, Orta Öğretim Fen ve Matematik Alanları Eğitimi

Tez Yöneticisi : Assoc. Prof. Dr. Safure Bulut

Ocak 2005, 78 sayfa

Bu çalışmanın amacı, okul türünün uzaysal yetenek üzerindeki etkisini, matematik başarısı ve mantıksal düşünme becerisi ile uzaysal yetenek arasındaki ilişkiyi, ve teknik resim dersinin uzaysal yeteneğin gelişmi üzerindeki etkisini araştırmaktır.

Araştırma Beypazarı-Ankara'daki genel, Anadolu, yabancı dil ağırlıklı, ticaret meslek ve endüstri meslek lisesine kayıtlı bulunan 251 dokuzuncu sınıf öğrencisiyle yürütülmüştür.

Bu araştırma için iki ölçme aracı kullanılmıştır: Uzaysal Yetenek Testi ve Mantıksal Düşünme Grup Testi. Uzaysal yetenek testi Ekstrom tarafından geliştirilmiş olan kart çevirme, küp karşılaştırma, kağıt katlama ve yüzey oluşturma testlerinden oluşmaktadır. İlk iki test uzaysal yeteneğin alt boyutlarından olan uzaysal yönelim yeteneğini ölçerken son iki test uzaysal görme yeteneğini ölçmektedir. Bu testler Türkçe'ye Delialioğlu tarafından çevrilmiştir (1996). Mantıksal düşünme testi Roadrangka, Yeany, ve Padilla tarafından geliştirilmiş ve Türkçe versiyonu Aksu, Beberoğlu ve Paykoç tarafından geliştirilmiştir (1990).

Elde edilen verileri analiz etmek için tek yönlü varyans analizi, Pearson korelasyonu ve t-test kullanılmıştır.

Çalışmanın sonuçları şunları göstermiştir: Okul türünün öğrencilerin uzaysal yeteneklerine anlamlı bir etkisi olmadığı bulunmuştur; matematik başarısı ve uzaysal yetenek arasında güçlü ve anlamlı pozitif bir ilişki bulunmuştur; mantıksal düşünme yeteneği ile uzaysal yetenek arasında anlamlı ve pozitif bir ilişki bulunmuştur; teknik resim başarısı ile uzaysal yetenek arasında anlamlı ve pozitif bir ilişki bulunmuştur; öğrencilerin teknik resim dersiyle uzaysal yeteneklerinde anlamlı bir gelişme olduğu bulunmuştur.

Anahtar Kelimeler: Uzaysal yetenek, uzaysal görme yeteneği, uzaysal yönelim yeteneği, teknik resim.

ACKNOWLEDGEMENTS

I wish to express my gratitude to Assoc. Prof. Dr. Safure Bulut for her sincere interest, patience and criticism throughout my study.

I wish to thank my mother and sister for their support during my study.

I wish to thank to my colleagues for their guidance and help during my study.

TABLE OF CONTENTS

LIST OF TABLES

TABLE

LIST OF ABBREVATIONS

SAT	: Spatial Ability Test
SOAT	: Spatial Orientation Ability Test
SVAT	: Spatial Visualization Ability Test
GALT	: Group Test of Logical Thinking
AHS	: Anatolian High School
FLHS	: Foreign Language High School
GHS	: General High School
CVHS	: Commercial Vocational High School
IVHS	: Industrial Vocational High School
Mach	: Mathematics Achievement
Tdach	: Technical Drawing Achievement
F	: F-Statistics
SD	: Standard Deviation
M	: Mean
df	: Degrees of Freedom
α	: Level of Significance
r	: Pearson Product Moment Correlation Coefficient
p	: Probability
Std. Error	: Standard Error
ANOVA	: Analysis of Variance
SPSS	: Statistical Packages for Social Science

CHAPTER 1

INTRODUCTION

Mathematics is one of the most important subjects, which is not only necessary for academic achievement but also for everyday life. Therefore, the students must learn mathematics. Because of the importance of mathematics, how to develop students' basic mathematical skills has been a crucial issue for the educators and teachers for years.

One of the desired suggestions to develop mathematical skills is to suitably emphasize and develop primary abilities such as spatial ability instead of just teaching mathematics (Bishop, 1980). Spatial ability was considered to be one of the primary abilities that seem especially important in learning and doing mathematics (Battista & Wheatley, 1989). Many studies found spatial skills were positively correlated with measures of mathematics performance (Battista, 1987; Hodgson, 1996; Tartre, 1990). Spatial abilities are claimed to be powerful tools for understanding and solving mathematics problems (Hodgson, 1996). The frequent use of tree diagrams, Venn-diagrams, charts and other figures to organize information and show relationships among components of a problem demonstrates the plausibility of this hypothesis (Tartre, 1990). Moreover, Geddes D. (1993) mentioned that geometric modeling is a powerful problem-solving skill and should be used frequently by both teachers and students. A simple diagram, such as a pie-shaped graph, a force diagram in physics, or a dot-and-line illustration of a network, can illuminate the essence of a problem and allow geometric intuition to aid in the approach to a solution.

As a result of these studies, in the present study the relationship between mathematics achievement and spatial abilities was investigated.

Research studies showed that spatial ability did not only influence mathematics achievement but also it was strongly linked to achievement in science (Tracy, 1987). Delialioğlu (1996, 1999) determined a significant and positive relationship between spatial ability and physics achievement. Pollrand and Seber (1984) explained that taking science courses developed spatial ability. Additionally, Tracy (1987) found out that, the greater spatial ability the students have leaded into the greater success in science. Therefore, in the present study the effect of types of school on spatial ability was also examined.

Spatial intelligence has a strong relationship to other intelligences and cognition as Gardner (1985) mentioned. Moreover, many studies showed that there was a relationship between logical thinking abilities and spatial abilities (Delialioğlu, 1996; Geddes, 1993; Tai, 2003). Geddes (1993) claimed that studying geometry, in other words developing spatial sense, provided opportunities for divergent thinking and creative problem solving while developing students' logical thinking abilities. Therefore in the present study, the relationship between spatial abilities and logical thinking abilities was also investigated.

Gutierrez (1989) noted that psychologists had been aware of the importance of visualization long time ago, and they had developed detailed theories to frame their work, and tools to observe and test the individuals.

All these studies highlight the importance of spatial ability. Therefore, the development of spatial ability has been a primary problem for the researchers, educators and teachers for many years.

Various studies insisted that spatial ability could be improved by education. For example, Burns (1984) expressed that, appropriate geometry experiences were useful for developing reasoning processes which in turn support problem solving skills children needed to understand arithmetic as well as geometric concepts.

Therefore how to develop spatial skills becomes an important problem for the educators. And the results showed that the types of activities used in the course may have a direct influence on the improvement of spatial ability (Robihaux, 2003). A number of researchers referred to the importance of learners' engaging with concrete spatial activities before being able to form and manipulate visual images (Bernie & Smith, 1999). Moreover, Dean also expressed that the studies showed that improvements in imaging were associated with the acquisition of concrete operations (1976).

Spatial ability has been valued in careers involving the need to interpret spatial information, also. For example, for many years, tests of spatial ability have been used extensively to predict aptitude towards careers involving aviation, engineering or technical drawing. Olkun (2003) stated that one could provide activities for improving middle grade students' spatial ability with engineering drawing applications. He stated that if the specific rules were taken out from the content, the remaining visualization skills that were very similar to what were being used in spatial ability measures.

Therefore, the relationship between spatial ability and technical drawing was investigated in the present study. Moreover, the development of spatial abilities with technical drawing was examined.

Consequently, in the present study, the effect of type of high school students' spatial ability was investigated. Moreover, the relationships between the students' mathematics achievement, logical thinking ability and their spatial ability were examined. The relationship between technical drawing course and the spatial ability of the students was also investigated. Lastly, the development of the students' spatial abilities with the technical drawing course was examined.

CHAPTER 2

LITERATURE REVIEW

In this chapter, the literature related to the present study is reviewed. Based on the content and the main objectives of the study, the literature is classified in to two sections; definitions of spatial ability, spatial visualization and spatial orientation, and the studies on spatial ability.

2.1. Definitions of Spatial Ability, Spatial Visualization and Spatial Orientation

In this section some definitions related to spatial ability, spatial visualization ability and spatial orientation ability will be given.

2.1.1. Definition of Spatial Ability

Despite the prominent role of the spatial ability, review of literature in this field indicates that there is no precise definition of the concept. Neither the researchers, nor the mathematics educators have an agreement about the terminology to be used in this field. For example the terms spatial skills, spatial ability or spatial visualization can be used instead of each other or one term, such as spatial visualization can be used in different meanings. There are several approaches to how spatial ability should be defined or classified.

The first identifiable study to examine and define spatial ability appeared when Thurstone (1938), who was studying primary mental abilities, defined a "space" factor. Thurstone classified spatial-visual aptitude as one of the primary mental abilities, generally defined as the ability to mentally manipulate shapes, sizes and distances in the absence of verbal or numerical symbols (Allyn & Bacon, 1989). Moreover, spatial skills are considered to include interpreting and making drawings, forming mental images, visualizing changes and generalizing about perceptions in the environment (Allyn & Bacon, 1989).

Additionally, Rhoades (1981) expressed that the ability to create a mental image of an object and then to manipulate it mentally has significant practical application in fields such as mathematics, physics, architecture, design and engineering , and such ability has been labeled as spatial visualization by Mc Gee in 1979.

Another definition of the spatial skills is given by Tartre (1990) as the mental skills concerned with understanding, manipulating, reorganizing or interpreting relationships visually. Where Battista (1998) used the term spatial ability for the ability to formulate mental images and to manipulate these images in the mind.

Visual Spatial Intelligence is defined by Gardener (in 'Frames of Mind') as the ability to perceive the visual world accurately, to perform transformations and modifications upon ones initial perceptions, and to be able to re-create aspects of ones visual experience, even in the absence of relevant physical stimuli. Gardner (1985) says that spatial intelligence entails a number of loosely related capacities: the ability to recognize instances of the same element; the ability to transform or to recognize the transformation of one element into another; the capacity to conjure up a graphic likeliness of spatial information (Allyn & Bacon, 1989).

On the other hand, imagery was considered to consist of those mental images that are produced by memory or imagination by Samuels & Samuels (1975) and visualization is considered to be a more complex version of simple imagery (Osberg, 1997). According to Osberg (1997), visualization takes mental images and adds an affective, almost visceral component, making the image stronger and potentially more meaningful. In other words, the process of visualization has the ability to generate physiological and emotional responses similar to that which we experience during "real-time" perceptions. Additionally, he also described the spatial relations as an understanding about the relationship between objects in space, both in dynamic and static environments and he defined rotation as the ability to mentally rotate objects in space, and be able to maintain orientation and attributes during that transition.

A further definition of visualization, or visual thinking was done by Yakimanskaya (1991) as the kind of reasoning based on the use of mental images. She mentioned that “spatial thinking” was a form of mental activity which makes it possible to create spatial images and manipulate them in the course of solving various practical and theoretical problems.

On the other hand the term spatial sense was used in the *Curriculum Standards* and it refers to “an intuitive feel for one’s surroundings and objects in them” (NCTM, 1989).

Spatial sense in mathematics is considered to involve the use of visualization and spatial reasoning to solve mathematics problems. As an example, Gutierrez (1989) gives the definition of “Visualization” in mathematics as the kind of reasoning activity based on the use of visual or spatial elements, either mental or physical, performed to solve problems or prove properties.

Where Sjönlinder (2000) accepts with spatial abilities as cognitive functions that enable people to deal with spatial relations, visual spatial tasks and orientation of objects in space. And Olkun (2003) defined the spatial ability as the mental manipulation of objects and their parts in two dimensional and three dimensional spaces.

In the present study the term *spatial ability* was considered as the ability to manipulate, reorganize or interpret relationships visually.

2.1.2. Definitions of Spatial Visualization and Spatial Orientation

While investigating the spatial ability, researchers mostly divided the spatial ability different sub-skills. There are several approaches about how spatial ability should be classified.

One of the classifications is done by Yakimanskaya (1991). She divided the spatial thinking activity two; the first one was the creation of mental images and the second one was their manipulation or use, where she defined a mental image as a mental representation of a mathematical concept or property containing information based on pictorial, graphical or diagrammatic elements; a spatial image was created from the sensory cognition of spatial relationships, and it might be expressed in a variety of verbal or graphical forms including diagrams, pictures, drawings, outlines etc.; spatial thinking was a form of mental activity which made it possible to create spatial images and manipulate them in the course of solving various practical and theoretical problems.

On the other hand, Bishop (1983) emphasized the two abilities in visualization; the first one was the visual processing of the information, including translation of abstract relationships and non-figural data in to visual terms, the manipulation and extrapolation of visual imagery, and the transformation of one visual image in to another. The second ability was the interpretation of figural information involving knowledge of the visual conventions and spatial vocabulary used in geometric work, graphs, charts and diagrams of all types and the reading and interpreting of visual images, either mental or physical, to get from them any relevant information that could help to solve a problem.

A more detailed subscription was given by Kosslyn (1980) and expressed that there were four processes applicable to visualization and mental images; 1. Generating a mental image from some given information, 2. Inspecting a mental image to observe its position or the presence of parts or elements, 3. Transforming a mental image by rotating, translating, scaling or decomposing it and lastly, 4. Using a mental image to answer questions.

Mc Gee (1979) considered ten different abilities distributed in to two classes; First class contains the abilities of spatial visualization:

1. Ability to imagine the rotation of a depicated object, the (un)folding of a solid, and the relative changes of position of objects in space.

2. Ability to visualize a configuration in which there is movement among its parts.

3. Ability to comprehend imaginary movements in three dimensions, and to manipulate objects in the imagination.

4. Ability to manipulate or transform the image of a spatial pattern in to other arrangement.

The second class includes the abilities of spatial orientation:

5. Ability to determine relationships between different spatial objects.

6. Ability to recognize the identity of an object when it is seen from different angles, or when the object is moved.

7. Ability to consider spatial relations where the body orientation of the observer is essential.

8. Ability to perceive spatial patterns and to compare them with each other.

9. Ability to remain unconfused by the varying orientations in which a spatial object may be presented.

10. Ability to perceive spatial patterns or to maintain orientation with respect to objects in space.

As a result of a meta-analysis of studies made between 1974 and 1982, Linn and Petersen (1985) made a classification of spatial tests into three distinct categories and labeled these categories spatial perception, spatial visualization and mental rotation. Spatial perception was defined as the ability to determine spatial relations despite distracting information and spatial visualization as the ability to manipulate complex spatial information when several stages were needed to produce the correct solution (Linn and Petersen, 1985). Mental rotation was defined by Linn & Petersen (1985) as the ability to rotate, in imagination, quickly and accurately two- or three-dimensional figures.

A slightly different definition of mental rotation was made by Kolb and Whishaw in 1990. They stated that mental rotation was the ability to adopt novel perspectives, to see the other side of things. Furthermore, Kolb and Whishaw (1990) divided the mental rotation aspect of the cognitive space into two categories, visualization and orientation, according to neurological representations. Visualization is the ability to manipulate or rotate two- or three-dimensional pictorially presented stimulus objects.

Wiley (1990) has developed a "Hierarchy of Visual Learning" model, which provided a structural framework for how one learns through the process of "visual cognition, visual production, and visual resolve." These stages were dependent upon one and other, and represented one's ability to mentally comprehend, store, retrieve, create, edit, and communicate spatial information.

In the present study the classification of Lohman given in the study of Phillipps in 1998 was used. Lohman (1979) identified two main aspects of spatial ability; spatial orientation and spatial visualization. *Spatial orientation* involved the ability to imagine how a given object or set of objects would appear from a spatial perspective different from that in which the objects are shown. According to Tartre (1990) spatial orientation skill appeared to be used in specific and identifiable ways in the solution of mathematics problems. These ways included accurately estimating the approximate magnitude of a figure, demonstrating the flexibility to change an unproductive mind set, adding marks to show mathematical relationships, mentally moving or assessing the size and shape of part of a figure, and getting the correct answer without help to a problem in which a visual framework was provided.

Spatial visualization, on the other hand, required complex mental rotation of one or more visualized objects such as those involved in mental power folding or rearrangement of pieces of an object to form the whole object.

2.2. Studies on Spatial Ability

In this section, studies on the importance of spatial ability, studies on how to develop spatial ability of the students and the studies on the relationship between the engineering (technical) drawing and the spatial ability of the students are summarized.

2.2.1. Studies on the Importance of Spatial Ability

Usiskin (1987) mentioned that "there is a consensus among mathematics educators and researchers that visualization, or spatial ability is important because it enhances a global and intuitive view and understanding in many areas of mathematics. Research studies show that there are relationships between spatial ability and geometrical achievement."

The literature contained a great deal of discussion about the possible relationship between spatial skills and mathematics. In the study of Tartre and Fennema (1985), middle school students were asked to draw pictures to solve mathematics problems. When asked to tell about the problem before solving it, students with high spatial visualization skill and low verbal skill translated the problem into a picture better and had more detailed information on the problems solved correctly.

A study was conducted by Hodgson (1996) with the university students to investigate the use of Venn diagrams to visualize set expressions. The results of the study showed that the translation of set expressions provided a rich content for studying students' formation and use of procedures, their understanding and operationalization of set operations, and their ability to establish connections between alternative representations of mathematical concepts.

On the other hand Hershkowitz (1989) discussed the two directions of the role of the visualization in geometry. First one was that, visualization was a necessary tool in geometrical concept formation, because the basic concepts in geometry were visual figures. The second side of the coin is that, unlike judgment based on mathematical definition, visual judgment did not make a clear cut distinction between concept examples and other instances. So, it put some limitations on the individual ability to form all the concepts' examples.

Another study by Battista et al., (1989) investigated the strategies and abilities used in the geometry problem solving of pre-service elementary teachers. The study showed that visualization strategy was used most frequently and it was indicated that effective use of the visualization strategy required high "general" ability or a high amount of some combination of abilities such as spatial visualization. Additionally, it was noted that student performance on the visualization tasks was best when the strategy used matched the level of spatial ability; high spatial students performed well when they adopted a constructive strategy and low spatial students performed well when they adopted analytic strategy.

Research studies indicated that spatial ability was also important for areas other than mathematics and geometry. Fennema and Sherman (1997) showed that it was spatial visualization that was more importantly related to mathematics achievement. Besides mathematics, spatial ability was found to be strongly linked to achievement in science (Delialioğlu, 1996; Elmore and Vasu, 1987; Tracy, 1990).

A study by Delialioğlu (1996) was with 9th grade students. In his study Delialioğlu investigated the contribution of students' logical thinking ability, mathematical skills and spatial ability on achievement in secondary school physics. As a result of this study he determined a significant and positive relationship between spatial ability and physics achievement.

Additionally, Tracy (1990) found out that there was a significant difference between the science achievements of the students that have spatial abilities at different levels; that is the students with high spatial abilities have high science achievement where students with low spatial abilities had low science achievement.

In a more general sense, it was claimed by researchers that there was a relationship between logical thinking ability and spatial ability. As an example a study was conducted by D. Tai (2003). The purpose of the study was to investigate the effects of cognitive style and spatial ability on the logical thinking and problem solving abilities of students with regard to programming language. Most of the efforts of study focused on developing and refining instructional materials, performing experimental teaching, and analyzing the experimental data. Study results included the following: students with high spatial ability scored significantly higher than those with low spatial ability in logical thinking ability.

Another study by Geddes D. (1993) mentioned that the relationship between geometry and deductive reasoning originated with the ancient Greek philosophers, and remains an important part of the study of geometry. A key ingredient of deductive reasoning was being able to recognize which statements had been justified and which had been assumed without proof. This was an ability which all students should develop in all areas, not just geometry, or even just mathematics. At first, deductive reasoning was informal, with students inferring new properties or relationships from those already established, without detailed explanations at every step. Later, deduction became more formal as students learn to use all permissible assumptions in a proof and as all statements are systematically justified from what has been assumed or proved before.

Moreover they claimed that studying geometry also provided opportunities for divergent thinking and creative problem solving while developing students' logical thinking abilities. Geometric concepts and representations could help students better understanding number concepts while being particularly well-suited for addressing the First Four Standards: problem solving, reasoning, making connections, and communicating mathematics. Students' experiences in learning geometry should help them perceive geometry as having a dynamically important role in their environment and not merely as the learning of vocabulary, memorizing definitions and formulas, and stating properties of shapes. Students, working in groups or independently, should explore and investigate problems in two and three dimensions, make and test conjectures, construct and use models, drawings, and computer technology, develop spatial sense, use inductive and deductive reasoning, and then communicate their results with confidence and conviction. They should be challenged to find alternative approaches and solutions.

Gardner (1985) was also a strong advocate of spatial intelligence and its relationship to other intelligences and cognition. In Gardner's view, spatial ability and spatial cognition were the basic building blocks that a child needed in order to develop higher level thinking skills, specifically those that complement verbal processing skill.

2.2.2. Studies on How to Develop Spatial Ability

Most of the researchers insisted that, there was a positive relationship between spatial training and the students' spatial skill enhancement (Herskowitz, Parzysz

& Van Dormolen, 1996; Olkun, 2003; Osberg, 1997; Owens&Clements, 1998; Owens&Clements, 1998; Pallascio & Allaire & Mongeau, 1993).

As an example, Olkun (2003) mentioned that, although there were somewhat conflicting results in the literature regarding whether spatial ability could be improved, numerous studies have indicated that it could be improved through training if appropriate materials are provided. Therefore the researchers focused on the types of exercises that will help the students to develop their spatial abilities.

Furthermore, Bennie and Smith (1999) insisted that spatial sense could not be taught, but had to be developed over a period of time. Moreover they stated that a number of researchers referred to the importance of learners engaging with concrete spatial activities before being able to form and to manipulate visual images. According to the study of van Niekerk (1995) an individual had experiences with a three-dimensional cube before being able to describe it verbally, made a mental image of the cube, or made a two-dimensional drawing of the cube.

Another study was carried out by Herskowitz (et al., 1996). In the study the effect of the Agam Program was investigated. The main goal of the Agam Program was to develop young children's abilities to perceive, think and create by using visual language. The Agam Program was a set of activities that helped the development of a visual language with a process of developing visual thinking. The program consisted of 36 units that introduce children to basic visual concepts and certain visual skills. The results of the study showed that Agam Program increased the general intelligence of the trained students in comparison with non-trained ones. Strong effect was also found on general school readiness, expressed in writing, geometry and logical thinking. Agam children demonstrated a significantly greater ability to identify visual concepts in complex contexts, a better understanding of these concepts and a better application of them in complex visual settings expresses that studies shows that improvements in imaging were associated with the acquisition of concrete operations and that success on the judgment version of a task is a prerequisite for success on the corresponding imaging version had been interpreted as support for Piaget's position (Dean, 1976).

The study of Owens and Clements (1998) supported this claim. The main problem of the study was, "How primary school students solve two dimensional spatio-mathematical problems, and how their environment in problem solving activities could assist them to develop and use visual imagery and spatial concepts." Moreover in the study the roles of responsiveness, visual imagery, and selective attention were described. They concluded that the making of shapes, the comparing of angles and the "finding" of shapes in the designs-with-matches task seemed to improve the students visualizing. The activities encouraged the students to dissembled shapes and parts from more complex shapes to imagine where other shapes such as angles and sides, and to consider what might be the result of systematic changes to shapes or configurations.

Another study that focuses on the improvement of spatial visualization was constructed by Battista (1989). In the study, pre- and post-test a group of elementary education majors enrolled in an informal geometry course which primarily used hand-on activities and manipulative aids. Results of this study yielded significantly higher spatial visualization scores on the post-test and on the pre-test. Thus the researchers concluded that the types of activities used in the course might have a direct influence on the improvement of spatial visualization ability.

Also, Beanninger and Newcombe (1989) found reliable relationship between spatial activity participation and spatial visualization ability. (Robichaux, 2003)

Other than studies on developing spatial ability activities Robichaux (2002) designed a research and primary objective of the research was to provide a theoretical explanation of the development of spatial visualization abilities. He concluded that, spatial visualization developed over a period of time as a result of one's experiences and certain exogenous qualities. Moreover, he mentioned that, spatial visualization was influenced by one's childhood experiences, which were found to be influenced by one's gender, parents' occupations and family income.

After this first study, another study of Robichaux (2003) was designed to gain a better understanding of the thinking processes that occur as one engages in spatial visualization activities and to improve the spatial visualization ability of the participant through the use of such activities. He concluded that, spatial visualization ability could be developed when real concrete objects were used over a period of time so that subsequently the user couldn't mentally utilize the concrete objects when presented tasks that were strictly in two dimensions. Additionally, he discussed that, mathematics teacher educators should engage their pre-service teacher students in hands-on activities similar to those used in this study and insisted that they, too, verbalize their thoughts. The results of this study suggested that engaging one in spatial tasks once a week every other week over the course of one semester while verbalizing one's thought processes did improve one's spatial visualization.

Pallascio (et. al., 1993) expressed the objective of the experiments that they highlighted was to study the development of spatial competencies through the use of activities focusing alternatively on analytic and synthetic competencies. At the end of the study they concluded that the development of spatial competencies in geometry by means of alternating analytic and synthetic activities had produced a number of results that could enrich the teaching of geometry. In the creation or generation of spatial representations, hands-on work with physical media was certainly important but it was also important not to create new obstacles to learning, where Battista and Clements (1998) suggested that structuring two dimensional and three dimensional spaces was the foundation for geometric and visual thinking. Where, spatial structuring an object determines its nature or shape by identifying its spatial components, combining components into spatial composites, and establishing interrelationships between and among components and composites. Moreover they insisted that all of geometry is, in essence, a way of structuring space and studying consequences of that structuring.

Another study by Osberg (1997) evaluated the effect of designing and experiencing a virtual world as a spatial processing skill enhancement method, and as an aid to cognitive development. As a result the data support the hypothesis that intensive training in three-dimensional thinking could help a child gain skills necessary for spatial cognition. Therefore, intensive training in three-dimensional thinking could help a child gain skills necessary for spatial cognition, where spatial cognition was the process by which a child perceived, stored, recalled, created, edited, and communicated about spatial images.

On the other hand a study by Zimmler and Keanen showed that spatial ability can be developed even without seeing. In their studies, they compared congenitally blind vs. sighted individuals who were asked to perform three different tests, all of which involved visualization of objects. In all cases, the blind individuals did better than sighted individuals recalling concepts that were auditory in nature. However, when comparing visual and auditory concept recall, blind subjects remembered more visual concepts than concepts in any other category. This led the researchers to believe that blind people do in fact visualize, at least in a fashion that works for them. The conclusions were that visualization was highly individualized, and that meaning could be developed regardless of the sense modality used to encode the information to begin with. Furthermore, visualization was a naturally occurring event, even in individuals blind from birth.

The researchers that deal with the cognitive developments of the students mentioned that not only the spatial trainings but also the age and the maturation were important on the development of students' spatial skills.

As an example, van Hieles, two Dutch educators studied children's development of geometric thought. At the end of their study they concluded that children pass through five levels of reasoning in geometry; visualization, abstraction, deduction and rigor. These levels were in much the same way that Piaget said children must precede through the stages in cognitive development. They proposed that progress through these five levels, is more dependent on instruction than on age or maturation. And moreover, research studies had shown that materials and teaching can be matched to the levels and promote growth.

Similarly, Patterson and Milakofsky (1980) stated that, the stage theory of childhood development as described by Piaget (1952) had a great deal of relevance when one discusses mental maturity for certain types of reasoning, specifically higher level thinking skills. Regardless of the order or the age at which these skills appear, Piaget was able to identify important components to spatial processing, such as the ability to comprehend perspective, transformations, ordinal relations, classification, kinetic imagery, reciprocity, transitivity, probability, and conservation .

Another study by Alias, Black and Gray (2002) mentioned that four stages of cognitive development have been suggested, that is, (i) the sensory-motor stage, (ii) the pre-operational stage, (iii) the concrete operational stage, and (iv) the formal operational stage. A person who was at the concrete operational stage "…always started with experience and made limited interpolations and extrapolations from the data available to his senses" (Piaget in Phillips, 1969, p. 104). On the other hand, a person at the formal operational stage did not need to experience in order to generate and evaluate propositions. As such, a formal operational thinker could be expected to make use of a variety of spatial possibilities and to have better spatial skills compared to those who have yet to reach this stage. According to Piaget and Inhelder (1971), children started to develop their formal operational skills at the age of 13; reaching their maximum potential by the age of 17, suggesting that students in post secondary education are formal operational thinkers. However, later studies had shown a high percentage of post-secondary students who had yet to reach the formal operational stage (Killian, 1979; Reesink, 1985). This had significant implications for teaching even in higher education, since reaching the formal operational stage was a result of a combination of maturation and experience. While maturation might come with age, experience was most likely to be the consequence of education.

Another similar study was in 1986 with college women. The results showed that the collage women that receive training in physics and the Euclidean reference system led to improvement on the water level task. Where the water-level (horizontality) test is a 15-item test required participants to draw a horizontal line representing the water level on a drawing of a tilted drinking glass. Participants were first shown an outline drawing of a drinking glass being held by a person and were informed that the glass was half full of water as indicated by the horizontal line. They were told that on the following pages the glass would be shown in various orientations, and that they should draw the line where it should appear, using the pencil and ruler provided (Li, 2000).

2.2.3. Studies on the Relationship between the Engineering (Technical) Drawing and Spatial Abilities

Alias, Black and Gray (2002) investigated in their studies, the aim of the study was to test whether manipulative and sketching activities could influence spatial visualization ability in engineering students. They mentioned that studies had shown that this ability influences academic achievements in engineering related subjects such as structural design (Alias *et. al.*, 2001), integral calculus (Turner, 1982), mathematics (Tillotson, 1985), computer aided design (Sorby, 1999), engineering problem solving (His *et al*, 1997) and chemistry (Pribyl and Bodner, 1987). Therefore they concluded that visualization ability is desirable among engineering students. According to them sketching and drawing (S&D) is one of the most commonly prescribed activities for developing spatial visualization ability in engineering students, as inferred from course outlines for engineering graphics. S&D was a phrase used to describe all activities of making rough pictures (sketches) of something using pen or pencil and standardized drawings such as engineering drawing. In sketching, the proportions and lengths were simply judged by eye while in standardized drawing the proportions and lengths follow a specific scale. Association between S&D activities and spatial visualization ability was supported by findings from spatial ability studies. A pre- and post-test quasi-experimental design was employed using two intact classes of civil engineering students from Malaysian polytechnics. As a result of the study the positive effects of teaching and learning on spatial visualization ability was found study. This study highlighted the role of concrete spatial activities in the development of spatial visualization ability in engineering students. Perhaps, more concrete activities should be provided to engineering students to give them the basis for imagination, as what one does not see or experience one cannot imagine. This study set out to establish causal relationships between teaching and learning of spatial skills and spatial visualization ability. Although the improvement in the components of the spatial visualization ability was varied, with the largest gain being on the engineering drawing tasks and the least on the mental rotation tasks the study did show that spatial visualization skills in general were improved after the teaching and learning activities.

Another study conducted by Baartmans,. and Sorby, (1996) was about how the spatial abilities of the engineering students could be developed. The article set out to "demonstrate the kinds of spatial skills needed by engineers for their work and to suggest activities for the geometry classroom that we had used to help build these skills." It discussed the standard drawing layout, creating orthographic views, inclined surfaces, and activities for the geometry classroom.

Olkun (2003) mentioned that, although there were somewhat conflicting results in the literature regarding whether spatial ability could be improved, numerous studies had indicated that it could be improved through training if appropriate materials were provided. Researches show that spatial ability was important and can be improved through appropriate activities. The purpose of Olkun's study was to provide activities for improving middle grade students' spatial ability with engineering drawing applications. In the study, engineering drawing was chosen as a context for two important reasons. First, it had practical base in real life situations. In many technical occupations, drawing conventions were required and taught. Basically, this skill involved representing objects in pictorial forms and visualizing objects from their drawings. Second, concrete experiences with geometrical objects and representing them in two-dimensional space were proved helpful in improving students' performance in spatial visualization.

"Engineering drawing was a means of graphical communication. It consisted of some technical rules or drawing conventions and visual skills. Technical rules provide standardization."

The spatial ability in technical drawing should supposedly involved, but was not limited to, the manipulation of different lines, curves, plane shapes, and solid figures, and the transformations among them. Drawing perspectives or imagining the real object from the orthographic views also involved mental integration. Some technical rules like alignment of the views, and line weights made the visualization easy to understand. If the specific rules were taken out from the content, there remain visualization skills that were very similar to what were being used in spatial ability measurements. There was research evidence (e.g., Ben-Chaim *et al.*, 1988; Ben-Chaim *et al.*, 1985, Smail, 1983) that spatial skills might be enhanced by introductory lessons in technical drawing and three-dimensional work in wood and metal. In the next section, some activity examples were provided for geometry classrooms in order to make the students familiar with the conventions of technical drawing.

In summary, educators and researchers had been aware of the importance of spatial ability for many years; however there was no precise definition of spatial ability.

The research studies showed that, there was a positive relationship between the students' mathematics achievement and spatial ability. Moreover it was concluded that spatial ability was not only important in mathematics achievement but also science achievement, and even for higher thinking abilities. The results of studies insisted that there was a strong relationship between the students' spatial abilities and their logical thinking abilities.

Additionally, researchers mentioned that spatial ability and technical drawing was inter-correlated. In other words to be successful in technical drawing course, students' spatial ability level should be high. Furthermore, studies find out that technical drawing activities help development of students' spatial activities.

CHAPTER 3

METHOD

This chapter includes research design, main and sub-problems of the study, hypotheses, definition of terms, variables, subjects, instruments, procedure, assumptions and limitations, internal and external validity of the present study.

3.1. Research Design of the Study

The purposes of the study were to investigate high school students' spatial abilities with respect to school types, to investigate the relationship between the students' mathematical achievement, logical thinking abilities and their spatial ability, to investigate the relationship between the technical drawing achievement of students enrolled to Industrial Vocational High School and their spatial ability, and to investigate the difference between the students' spatial ability before and after taking the technical drawing course. Therefore, the study was a casual-comparative and correlational study.

The Spatial Ability Test (SAT) and the Group test of Logical Thinking (GALT) were administered in the present study. Spatial Ability Test is a paper-pencil test designed to measure students' spatial orientation ability and spatial visualization ability. GALT is designed to measure students' logical thinking abilities.

SAT and GALT were administered to 251 9^{th} grade students enrolled to five different kinds of schools: General High School (GHS), Anatolian High School

(AHS), Foreign Language High School (FLHS), Industrial Vocational High School (IVHS) and Commercial Vocational High School (CVHS) in Beypazarı, Ankara.

3.2. Main and Sub-Problems of the Study and Associated Hypotheses

In this section main and sub problems and hypotheses are stated.

3.2.1. Main and Sub-Problems of the Study

The main problems and their sub-problems of the present study are the following:

P1. What is the effect of type of high school on the students' spatial ability?

P1.1. Are there any statistically significant differences among the scores of the students who enrolled to the different types of high schools with respect to their spatial ability?

P1.2 Are there any statistically significant differences among the scores of the students who enrolled in the different type of high school with respect to their spatial visualization ability?

P1.3. Are there any statistically significant differences among the scores of the students who enrolled in the different types of high schools with respect to their spatial orientation ability?

P.2. What are the relationships between the students' mathematics achievement, logical thinking ability and their spatial ability?

P.2.1. Is there a significant relationship between the students' spatial ability and their mathematics achievement?

P.2.2. Is there a significant relationship between the students' spatial visualization ability and their mathematics achievement?

P.2.3. Is there a significant relationship between the students' spatial orientation ability and their mathematics achievement?

P.2.4. Is there a significant relationship between the students' spatial ability and their logical thinking ability?

P.2.5. Is there a significant relationship between the students' spatial visualization ability and their logical thinking ability?

P.2.6. Is there a significant relationship between the students' spatial orientation ability and their logical thinking ability?

P.3. What is the relationship between the IVHS students' technical drawing achievement and their spatial ability?

P.3.1. Is there a significant relationship between the IVHS students' spatial ability and their technical drawing achievement?

P.3.2. Is there a significant relationship between the IVHS students' spatial visualization ability and their technical drawing achievement?

P.3.3. Is there a significant relationship between the IVHS students' spatial orientation ability and their technical drawing achievement?

P.4. What is the students' spatial ability before and after taking the technical drawing course?

P.4.1. Is there a significant mean difference between the pre-test and post-test spatial ability scores of the IVHS students?

P.4.2. Is there a significant mean difference between the pre-test and post-test spatial visualization scores of the IVHS students?

P.4.3. Is there a significant mean difference between the pre-test and post-test spatial orientation scores of the IVHS students?

3.2.2. Hypotheses of the Study

In order to examine the sub-problems the following hypotheses are stated. These hypotheses are stated in the null form and tested at a significance level of 0.05.

- **H1.1.** There are no statistically significant mean differences among the mean scores of the students enrolled to different types of high schools with respect to spatial ability.

- **H1.2.** There are no statistically significant differences among the mean scores of the students enrolled to different types of high schools with respect to spatial visualization ability.

- **H1.3.** There are no statistically significant differences among the mean scores of the students enrolled to different types of high schools with respect to spatial orientation ability.

- **H2.1.** There is no statistically significant relationship between the students' spatial ability and their mathematics achievement by controlling type of high school.

- **H2.2.** There is no statistically significant relationship between the students' spatial visualization ability and their mathematics achievement by controlling type of high school.

- **H2.3.** There is no statistically significant relationship between the students' spatial orientation ability and their mathematics achievement by controlling type of high school.

- **H2.4.** There is no statistically significant relationship between the students' spatial ability and their logical thinking ability.

- **H2.5.** There is no statistically significant relationship between the students' spatial visualization ability and their logical thinking ability.

- **H2.6.** There is no statistically significant relationship between the students' spatial orientation ability and their logical thinking ability.

- **H3.1.** There is no statistically significant relationship between IVHS students' spatial ability and their technical drawing achievement.

- **H3.2.** There is no statistically significant relationship between IVHS students' spatial visualization ability and their technical drawing achievement.

- **H3.3.** There is no statistically significant relationship between IVHS students' spatial orientation ability and their technical drawing achievement.

- **H4.1.** There is no statistically significant mean difference between the pre-test and post-test spatial ability scores of IVHS students.

- **H4.2.** There is no statistically significant mean difference between the pre-test and post-test spatial visualization ability scores of IVHS students.

- **H4.3.** There is no statistically significant mean difference between the pre-test and post-test spatial orientation ability scores of IVHS students.

3.3. Definition of Terms

Spatial ability: Spatial ability means mental skills concerned with understanding, manipulating, reorganizing or interpreting relationships visually. In the present study spatial ability score refers to the sum of the spatial visualization score and spatial orientation score.

Spatial visualization: Spatial visualization is the ability to determine what a give pattern or configuration would be if it were alerted so that the parts occupied a different relationship to another. In the present study spatial visualization ability score refers to the sum of paper folding test score and surface development test score.

Spatial orientation: Spatial orientation is the ability to rotate the solid figures in all planes and to orient spatially with respect to a given object or scene. In the present study spatial visualization ability score refers to the sum of card rotation test score and cube comparison test score.

School types: It refers to the five different types of high schools: Anatolian High School, Foreign Language High School, General High School, Commercial Vocational High School and Industrial Vocational High School.

Technical drawing (engineering drawing) achievement: It refers to the technical drawing course GPA scores of the 9^{th} grade IVHS students and the scores are given over 5.

Mathematics achievement: It refers to the mathematics GPA scores of the students at the end of the 9^{th} grade and the scores are given over 5.

Logical thinking ability: It refers to the group test of logical thinking (GALT) scores of the students.

3.4. Variables

The variables of the present study can be considered in four parts. The first part includes the variables of the first problem of the study –"What is the effect of types of high school on the students' spatial ability?" The dependent variables for the first problem are SAT scores, SVAT scores and SOAT scores of the students, where the pre-test scores of the Industrial Vocational High School students are used. On the other hand the independent variable is the high school type.

The variables for the second problem of the present study –" What is the relationship between the students' mathematics achievement, logical thinking ability and their spatial ability?" are considered to be spatial ability, spatial visualization ability, spatial orientation ability, mathematics achievement and logical thinking ability of the high school students.

The variables for the third problem of the present study –"What is the relationship between the IVHS students' technical drawing achievement and their spatial ability?" are as follows: spatial ability, spatial visualization ability, spatial orientation ability and technical drawing achievement of IVHS students.

The variables for the fourth problem of the present study -"What is the students' spatial ability before and after taking the technical drawing course?" are stated as: the pre-test and post-test scores of the students they got from spatial ability, spatial visualization ability and spatial orientation ability.

3.5. Subjects of the Study

The subjects of the study are 251 9^{th} grade students (170 boys and 51 girls) enrolled in eight classrooms in five different schools that of each are different types. (Anatolian High School (30), Foreign Language High School (33), General High School (32), Commercial Vocational High School (32) and Industrial Vocational High School (96)) in Beypazarı – Ankara. In the study the sampling was convenient.

The study was carried out during the 2003-2004 academic year. The Spatial Ability Tests (SAT) and Group Test of Logical Thinking (GALT) were administered to the students from Anatolian High School, Foreign Language High School, General High School and Commercial Vocational High School at the fall semester of 2003-2004 academic year. On the other hand, SAT was administered to the students from Industrial Vocational High School as pre-test at the beginning of the fall semester of the 2003-2004 academic year and as post-test at the end of the spring semester of the 2003-2004 academic year.

The number of students from IVHS participated in the study is higher than the number of students from other schools, because the difference between the pre-test and post-test SAT results of the IVHS students is investigated in the study where the SAT scores of the students from other high schools are only used to investigate the effect of the school type.

The students from five different kinds of schools participated in the study and these schools have different conditions while accepting students. To go to the Anatolian High School the students should pass the LGS examination that is administered at the end of the 8^{th} grade. On the other hand, to continue their high school education in Foreign Language High School, the students' average grades in the first eight years should be higher then 4 over 5.

3.6. Measuring Instruments

In the present study, the following measuring instruments were used;

1- Spatial Ability Test (SAT)

2- Group Test of Logical Thinking (GALT)

3.6.1. Spatial Ability Test (SAT):

The Spatial Ability Test (SAT) is paper-pencil test that is used to establish the overall spatial ability. The SAT was developed by Ekstrom (1976) and translated in to Turkish by Delialioğlu (1996). It consists of two sub-tests, spatial visualization ability test and spatial orientation ability test. The sample questions for each test are given in Appendix A. The number of questions for each test is given in Table 3.1. The score of the SAT is obtained by the summation of these two tests.

Table 3.1 Reliability Coefficients, Number of Questions, Total Scores and the Durations for the Tests

	TESTS	RELIABILITY	NUMBER OF QUESTIONS AND TOTAL SCORES	DURATION
SVAT				
I)	PFT	0.84	20	12 MINUTES
II)	SDT	0.82	60	6 MINUTES
SOAT				
I)	CRT	0.80	160	6 MINUTES
II)	CCT	0.84	42	6 MINUTES

The sub-tests of the SAT administrated for the study are:

Spatial Visualization Ability Test:

It consists of two sub-tests: Paper Folding Test (PFT) and Surface Development Test (SDT). Reliability coefficient, number of questions, total score of each test and duration required for each test is given in Table 3.1. The score of the spatial visualization ability test (SVAT) is obtained by the summation of the scores of PFT and SDT.

(i) Paper Folding Test (PFT): It consists of multiple choice items that require imagining folding and unfolding a piece of paper. In the evaluation of test, each true choice is one point. Since there are 20 questions, the score of PFT is over 20.

(ii)Surface Development Test (SDT): It requires imagining the development of different objects by folding a piece of paper, and consists of matching items. In each question there are five answers to match and each true matching is one point. Since there are 12 questions the score of SDT is over 60.

Spatial Orientation Ability Test

It consists of two sub-tests: Card Rotation Test (CRT) and Cube Comparison Test (CCT). In Table 3.1 reliability coefficient, number of questions, total score of each test and duration required for each test is given. The score of the spatial orientation ability test (SOAT) is the summation of the scores obtained by CRT and CCT

(iii)Card Rotation Test (CRT): This test is developed to measure the ability to see the differences between the shapes and consists of true-false items. Each true answer is scored as 1 and there are 42 items, therefore the test is scored over 42.

(iv)Cube Comparison Test (CCT) : In all the questions in this test there are cubes that have six faces with different numbers, figures or letters on each surface and one should find out whether the given cubes are the same or not, so the test contains true-false items. In each question there are 8 items and for each true item one gets 1 point. Since there are 20 questions the total score is 160.

3.6.2. Group Test of Logical Thinking (GALT)

The GALT was originally developed by Roadrangka, Yeany, and Padilla at the University of Georgia in 1982. It consists of 21 problems that require the application of logical operations. The test is used to assess subjects' logical thinking from a Piagetian perspective. It contains problems related to identifying and controlling variables, and proportional, correlational, probabilistic and combinatorial reasoning. For each problem, students first choose a correct answer from among five alternatives and then choose a reason from among five alternatives. Both answers for each problem must be correct before the item is scored positively. This format minimizes the effect of guessing and results in high reliabilities for the total test and subtests. Only the combinatorial reasoning items were different from this format. In these questions, students list the possible combinations of several variables.

A Turkish version of the GALT was developed by Aksu, Beberoğlu and Paykoç (1990), and they found the alpha reliability coefficient as 0. In the present study the Turkish version was administered.

3.7. Procedure

The present study started with a review of literature about the intended components of the research question.

Before administering the tests, the necessary permissions were obtained from the Beypazarı Directorate of Education. The study was carried out in the 2003-2004 academic year. The SAT had also been translated Turkish and had been administered by Delialioğlu (1996) and the GALT had been translated in to Turkish by Aksu, Beberoğlu and Paykoç (1990). In the present study the Turkish versions of the tests were used.

The SAT was administered to students during the determined durations and the GALT was administered to the students in one hour of each school therefore all the students answered the tests at the same determined time. All the tests were administered by the researcher to all of the students in their classrooms. Before the administration of the tests, the purpose of the study and the directions were explained to the students. In addition, before administering each part of the SAT the students were given instructions about how to answer the part.

The students of the technical vocational high school took the technical drawing course which is a one-year period course. The 9^{th} grade students take the course as a compulsory course and the one-year course plan is given in Appendix B.

At the beginning and end of the academic the SAT was administered to IVHS students as pre-test and post-test. The way of administration was the same as the first administration.

3.8. Analyses of the Data

Data analyses of the study were conducted by the following statistical techniques;

- Data of the present study were analyzed by using the SPSS package program.

- Data collected from the subjects were coded by the following techniques:

    - Students' scores for each part of the SAT and the GALT were transferred to computer environment by SPSS package program.

    - Anatolian High School, General High School, Foreign Language High School, Commercial Vocational High School and Industrial Vocational High School were coded from 1 to 5 respectively.

    - Cumulative mathematics course scores and cumulative technical drawing course scores of the students in the 2003-2004 academic year were coded from 0 to 5 as given below;

0-24……..0	25-44……1	45-54……2
55-69……3	70-84……4	85-100…..5

- Descriptive statistics were used by the following reasons:

    - To get the means and standard deviations of the students' SAT and GALT scores.

    - To find the distribution of the number and the frequencies of the subjects.

    - To detect the outliers and to check that data recording error was made (data cleaning).

- The relationship between the measures in the study was presented by using Pearson Product Moment Correlation Coefficient.

- T-test was used to find whether there are significant mean differences between the students pretest and post test scores of SAT.

- One way ANOVA was used by the following reasons:
    - To determine whether there are significant mean differences among groups with respect to their SAT scores.
    - To determine the differences between the dependent variables simultaneously.
- α was set to be 0.05 as the probability of doing a Type I error.

3.9. Assumptions and Limitations

In this section, assumptions and limitations of the present study are discussed.

3.9.1. Assumptions

The main assumptions of the present study are the following:

- There was no interaction between the subjects to affect of the present study.
- The subjects were able to understand and interpret the items truly.
- The administration of the tests was completed under standard conditions.
- All subjects answered the measuring instruments accurately and sincerely.

3.9.2. Limitations

The limitations of the present study are listed below:

- The selection of the subjects for the survey did not comprise a random sampling. Therefore, the sample may not be fully representative of the population and the generalizability is limited.
- This study was limited to subjects at the ninth grades of the high schools in rural areas of Ankara during 2003-2004 academic years.
- This investigation was based on self-report data, which may be subject to bias.

3.10. Validity of the Study

In this section internal and external validity of the study is discussed.

3.10.1. Internal Validity

Internal validity of a study means that observed differences on the dependent variable, not due to some other unintended variable (Fraenkel & Wallen, 1996).

One possible threat to internal validity of a study is subject characteristics. In the present study, all the students were at the same grade level so almost all the subjects' ages were close to each other. Also, the study was conducted in the schools of the same district of Ankara so the effect of students' socioeconomic backgrounds was controlled.

Administering the tests to all ninth grades of the schools almost at the same time controlled location threat.

To control the data collectors' characteristics and data collector bias, all data were collected by the researcher.

3.10.2. External Validity

External validity is extending to which the results of a study can be generalized (Fraenkel & Wallen, 1996).

3.10.2.1. Population Validity

In the present study the sampling was convenient sampling, therefore the generalizations of the findings of the study were limited. On the other hand, generalizations can be done on the subjects having the same characteristics with the subjects of the present study which were mentioned in the "subjects of the Study" section.

3.10.2.2. Ecological Validity

Fraenkel and Wallen (1996) expressed that the ecological validity is the degree to which results of a study can be extended to other setting or conditions. The measuring instruments were used in regular classroom settings. The study is on ninth grade high school students, therefore the results of the study can be generalized to similar settings to this study.

CHAPTER 4

RESULTS AND CONCLUSIONS

In the previous chapters, the theoretical background of the study, the review of the previous studies and the method of the present study were stated. In this chapter, the results of the analyses that are conducted to obtain statistical evidence for our claims will be presented. This chapter contains three sections. The first section presents the descriptive statistics. The second section is the inferential statistics section where the results of the testing hypotheses associated to the problems are included. Finally, the third section of the chapter includes the conclusions derived from the present study.

4.1. Descriptive Statistics

In this section the descriptive statistics of the data are given and the row scores are used.

Table 4.1 shows the means and standard deviations, maximum and minimum values of the variables (SAT scores, SOAT scores, and SVAT scores) with respect to the type of school.

Table 4.1 Means, Standard Deviations and Maximum and Minimum Values of the SAT, SOAT and SVAT Scores with respect to type of High Schools.

School Type		n	Minimum	Maximum	Mean	SD
AHS	SAT	30	89.00	218.00	148.80	37.37
	SOAT		63.00	180.00	124.47	33.47
	SVAT		11.00	51.00	24.33	10.46
FLHS	SAT	33	75.00	215.00	144.67	34.43
	SOAT		62.00	190.00	119.70	30.88
	SVAT		12.00	46.00	24.97	9.36
GHS	SAT	32	85.00	229.00	147.75	31.77
	SOAT		68.00	194.00	119.94	30.39
	SVAT		14.00	44.00	27.81	6.76
CVHS	SAT	30	91.00	210.00	142.30	27.59
	SOAT		57.00	184.00	120.90	27.57
	SVAT		12.00	34.00	21.40	5.13
IVHS	SAT	96	70.00	217.00	137.39	32.83
	SOAT		56.00	179.00	117.93	29.45
	SVAT		6.00	42.00	19.46	7.51

4.2. Inferential Statistics

In this section, the sub-problems of the study will be examined by means of their associated hypotheses which are in the null form and tested at a significance level of 0.05.

4.2.1. Results of Testing of First Problem

The first problem (P1) is: “What is the effect of type of high schools on the students’ spatial ability?”

For the first sub-problem the following hypotheses is stated:

H1.1. “There are no statistically significant mean differences among the mean scores of the students enrolled in different type of high school with respect to spatial ability.”

To test this hypothesis, one way Analyses of Variance (ANOVA) is used. One of the main assumptions is the homogeneity of variances. When the test of homogeneity of variances investigated, it is concluded that for the SAT the variances are homogeneous ($p > 0.05$).

Table 4.2 Results of one way ANOVA for the SAT Scores with respect to Type of High School

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4718.85	4	1179.71	1.09	0.36
Within Groups	234217.17	216	1084.34		
Total	238936.02	220			

As seen in Table 4.2, the results of show that there are no statistically significant differences among the mean scores of students who enrolled in different types of high schools with respect to their spatial ability ($p > 0.05$).

Although the mean differences are not statistically significant there are slight mean differences (See table 4.1). The SAT scores of the students of Anatolian High School are the highest among the students from all other schools ($M_{AHS} = 148.80$, $SD_{AHS} = 37.37$). The General School students' SAT scores' mean is the second highest mean score ($M_{GHS} = 147.75$, $SD_{GHS} = 34.43$). Foreign Language High School students have the third highest mean score ($M_{FLHS} = 144.67$, $SD_{FLH} = 31.77$) and the Commercial Vocational High School students have the forth highest mean score ($M_{CVHS} = 142.30$, $SD_{CVHS} = 27.59$). The least mean score belongs to the students of Industrial Vocational High School ($M_{IVHS} = 137.39$, $SD_{IVHS} = 32.83$).

For the second sub-problem of the first problem the following hypotheses is stated:

H1.2. "There are no statistically significant differences among the mean scores of the students enrolled in different type of high school with respect to spatial visualization ability."

To test this hypothesis, again one way ANOVA is used.

The variances are not homogeneous for the Spatial Visualization Ability Tests (SVAT) scores ($p < 0.05$). Therefore the homogeneity of variances assumption of ANOVA is not satisfied. To have the variances homogeneous, the "sine" transformation is conducted for the SVAT scores and it is seen that the variances become homogeneous ($p > 0.05$).

Table 4.3 Results of one way ANOVA for SVAT Scores with respect to Type of High School

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.69	4	0.17	0.34	0.85
Within Groups	108.90	216	0.50		
Total	109.60	220			

As seen in the Table 4.3, the results indicate that there are no statistically significant differences among the mean scores of students who enrolled to different types of high schools with respect to their spatial visualization ability ($p > 0.05$).

On the other hand, when the mean differences are examined it can be seen that there are slight differences. Mean score of the students in the GHS is the highest ($M_{GHS} = 27.81$, $SD_{GHS} = 6.76$), and then comes the mean score of the FLHS students ($M_{FLHS} = 24.97$, $SD_{FLHS} = 9.36$), the third highest mean score belong to AHS students ($M_{AHS} = 24.33$, $SD_{AHS} = 10.46$); the fourth highest mean score belongs to the CVHS ($M_{CVHS} = 21.40$, $SD_{CVHS} = 5.13$), and mean SVAT score of IVHS students is the least ($M_{IVHS} = 19.46$, $SD_{IVHS} = 7.51$) (See Table 4.1).

Lastly hypothesis of the third sub-problem of the first problem is stated as:

H1.3. "There are no statistically significant differences among the mean scores of the students enrolled in different type of high school with respect to spatial orientation ability."

To examine the third hypothesis of the first problem of the study, one way ANOVA is used.

When examined, it is concluded that for the Spatial Orientation Ability Tests (SOAT) ($p > 0.05$) the variances are homogeneous.

Table 4.4 Results of one way ANOVA for SOAT Scores with respect to Type of High School

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1027.19	4	256.80	0.28	0.89
Within Groups	196081.50	216	907.79		
Total	197108.69	220			

The results reveal that there are no statistically significant differences among the mean scores of students who enrolled in different type of high school with respect to their spatial orientation ability ($p>0.05$). However, there are slight mean differences as the SAT and the SVAT. As seen in the Table 4.1 the AHS students' SOAT mean score is the highest over all other school students' mean scores ($M_{AHS} = 124.47$, $SD_{AHS} = 33.47$). Different than the SAT scores, the second highest SOAT mean score belongs to the students of the CVHS ($M_{CVHS} = 120.90$, $SD_{CVHS} = 27.57$). Then comes the mean scores of the GHS students ($M_{GHS} = 119.94$, $SD_{GHS} = 30.39$). The least two scores belong to the students of the FLHS ($M_{FLHS} = 119.70$, $SD_{FLHS} = 30.88$) and IVHS ($M_{IVHS} = 117.93$, $SD_{IVHS} = 29.45$).

4.2.2. Results of Testing of Second Problem

The second problem (P2) is stated as: "What is the relationship between the students' mathematics achievement, logical thinking ability and their spatial ability?"

The hypotheses for the first three sub-problems of the second problem are stated as follows:

H2.1. “There is no statistically significant relationship between the students’ spatial ability and their mathematics achievement by controlling the type of school.”

H2.2. “There is no statistically significant relationship between the students’ spatial visualization ability and their mathematics achievement by controlling the type of school.”

H2.3. “There is no statistically significant relationship between the students’ spatial orientation ability and their mathematics achievement by controlling the type of school.”

To examine the hypotheses H2.1, H2.2 and H2.3, the Pearson Product Moment Correlation Coefficient is used, and each hypothesis is tested for each of the high schools separately.

Table 4.5 Pearson Product Moment Correlation Coefficients of SAT, SVAT and SOAT Scores and the Mathematics Achievement of the Students from Five Different High Schools

	Correlation Coefficient				
	AHS	FLHS	GHS	CVHS	IVHS
SAT- mach	0.68*	0.62*	0.58*	0.60*	0.63*
SVAT - mach	0.42*	0.36*	0.33*	0.30*	0.35*
SOAT - mach	0.65*	0.59*	0.61*	0.58*	0.60*

* $p < 0.05$

As seen in Table 4.5 there is a statistically significant positive relationship between the spatial ability of the students from all of the five high schools and their mathematics achievement ($r_{AHS} = 0.68$, $r_{FLHS} = 0.62$, $r_{GHS} = 0.60$, $r_{CVHS} = 0.58$, $r_{IVHS} = 0.63$; $p < 0.05$). Also, the results show that the correlation between spatial visualization ability of the students from all of the five high schools and their mathematics achievement is statistically significant and positive (r_{AHS} = 0.42, r_{FLHS} = 0.38, r_{GHS} = 0.33, r_{CVHS} = 0.30, r_{IVHS} = 0.35; $p < 0.05$). Furthermore, spatial orientation ability of the students from all of the five high schools are statistically significantly correlated to their mathematics achievement (r_{AHS} = 0.65, r_{FLHS} = 0.59, r_{GHS} = 0.61, r_{CVHS} = 0.58, r_{IVHS} = 0.60; $p < 0.05$). According to the Pearson Product Moment Correlation Coefficients, the relationship between the students' spatial ability and mathematics achievement is as strong as the relationship between the correlation between the students' spatial orientation ability and mathematics achievement. On the other hand the relationship between the students' spatial visualization ability and mathematics achievement is moderate.

For the fourth, fifth and the sixth sub problems of the second problem the following hypotheses are stated:

H2.4. "There is no statistically significant correlation between the students' spatial ability and their logical thinking ability"

H2.5. "There is no statistically significant correlation between the students' spatial visualization ability and their logical thinking ability."

H2.6. "There is no statistically significant correlation between the students' spatial orientation ability and their logical thinking ability."

The hypotheses H.2.4, H.2.5 and H.2.6 were tested by the Pearson Product Moment Correlations of SAT, SOAT and SVAT with GALT scores of students, are used.

Table 4.6 Pearson Product Moment Correlation Coefficients of SAT, SVAT and SOAT Scores and GALT Scores of the Students

	Correlation Coefficient
SAT- GALT	0.49*
SVAT - GALT	0.28*
SOAT - GALT	0.48*

* $p< 0.05$

When Table 4.6 is examined, it is seen that there is a statistically significant correlation between the spatial ability of the students and their logical thinking ability ($r = 0.49$, $p< 0.05$). Also, it can be concluded from the results that, the spatial visualization ability and the logical thinking ability of the students are statistically significantly correlated ($r = 0.28$, $p< 0.05$), but not as strongly as spatial ability and logical thinking ability. There is a statistically significant correlation between the students' spatial orientation ability and their logical thinking ability ($r = 0.48$, $p< 0.05$).

4.2.3. Results of Testing of Third Problem

The third problem (P3) is "What is the relation between the IVHS students' technical drawing achievement and their spatial ability?"

For the third problem the following hypotheses are stated to test its sub-problems:

H3.1. "There is no statistically significant correlation between IVHS students' spatial ability and their technical drawing achievement."

H3.2. “There is no statistically significant correlation between IVHS students’ spatial visualization ability and their technical drawing achievement.”

H3.3. “There is no statistically significant correlation between IVHS students’ spatial orientation ability and their technical drawing achievement.”

These hypotheses were tested by using Pearson Product Moment Correlation Coefficient and the results are given in Table 4.7.

Table 4.7 Pearson Product Moment Correlation Coefficients of SAT Scores and the Technical Drawing Achievement of the Students

	Correlation Coefficient
SAT- tdcach	0.21 *
SVAT - tdcach	0.12
SOAT - tdcach	0.21*

* $p < 0.05$

As seen in Table 4.7, there is a statistically significant correlation between the spatial ability of the IVHS students and their technical drawing achievement ($r = 0.21$, $p < 0.05$). Also the spatial orientation ability of the IVHS students are statistically significantly correlated with the technical drawing achievement ($r = 0.21$, $p < 0.05$). On the other hand there is not a statistically significant correlation between the IVHS students’ spatial visualization ability and their technical drawing achievement ($r = 0.12$, $p > 0.05$).

4.2.4. Results of Testing of Fourth Problem

The fourth problem (P4) is "What is the students' spatial ability before and after taking the technical drawing course?"

H4.1. "There is no statistically significant mean difference between the pre-test and post-test spatial ability scores of IVHS students."

H4.2. "There is no statistically significant mean difference between the pre-test and post-test spatial visualization ability scores of IVHS students."

H4.3. "There is no statistically significant mean difference between the pre-test and post-test spatial orientation ability scores of IVHS students."

These hypotheses were tested by using Pearson Product Moment Correlation Coefficient and the results are given in Table 4.8.

Table 4.8 Results of t-test Related to the Pre-test and Post-test Scores of the SAT, the SOAT and the SVAT Scores.

	Paired Differences					
	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
SAT post –pre	14. 08	13.15	1.34	10.50	95	0.00
SOAT post-pre	9.04	12.02	1.23	7.37	95	0.00
SVAT post-pre	5.04	6.50	0.66	7.60	95	0.00

As seen in Table 4.8 there is statistically significant mean difference between the pre and post SAT scores ($p < 0.05$). Since, the gained mean score is positive, it can be derived that the post- test spatial ability scores of the students are statistically significantly higher than the pre-test spatial ability scores of the students of IVHS ($M_{post\text{-}pre\ SAT} = 14.08$, $SD_{post\text{-}pre\ SAT} = 13.15$). Moreover, the mean difference between the pre-test and post-test spatial orientation scores is statistically significant ($p< 0.05$) and the gained spatial orientation ability score is also positive ($M_{post\text{-}pre\ SOAT} = 9.04$, $SD_{post\text{-}pre\ SOAT} = 12.02$). So, the post-test spatial orientation ability scores of the IVHS students are statistically significantly higher than the students' pre-test spatial orientation ability scores. Lastly, there is a statistically significant relationship between pre-test and post-test spatial visualization ability scores of IVHS students ($p < 0.05$) and the gained mean score is again positive that means the post-test spatial visualization ability scores are higher than the pre-test spatial visualization ability scores ($M_{post\text{-}pre\ SVAT} = 5.04$, $SD_{post\text{-}pre\ SVAT} = 6.50$).

4.3. Conclusions

In the light of the above findings obtained by examining of each hypothesis, the following conclusions can be deduced:

1- The type of school does not have an effect on the students' spatial abilities.

2- The type of school does not affect the students' spatial visualization abilities.

3- The type of school does not affect the students' spatial orientation abilities.

4- There is a strong positive relationship between the students' spatial ability and mathematics achievement.

5- There is a positive relationship between the students' spatial visualization ability and mathematics achievement.

6- There is a strong positive relationship between the students' spatial orientation ability and mathematics achievement.

7- There is a strong positive relationship between the students' spatial ability and logical thinking ability.

8- There is a positive relationship between the students' spatial visualization ability and logical thinking ability.

9- There is a strong positive relationship between the students' spatial orientation ability and logical thinking ability.

10- There is a positive relationship between the industrial vocational high school students' spatial ability and their technical drawing achievement.

11- There is no relationship between the industrial vocational high school students' spatial visualization ability and their technical drawing achievement.

12- There is a positive relationship between the industrial vocational high school students' spatial orientation ability and their technical drawing achievement.

13- There is statistically significant mean difference between the industrial vocational high school students' pre-test and post-test results with respect to their spatial ability in favor of post-test.

14- There is statistically significant mean difference between the industrial vocational high school students' pre-test and post-test results with respect to their spatial visualization ability in favor of post-test.

15- There is statistically significant mean difference between the industrial vocational high school students' pre-test and post-test results with respect to their spatial orientation ability in favor of post-test.

CHAPTER 5

DISCUSSION AND RECOMMENDATIONS

This chapter includes discussion and interpretation of the results and some recommendations for further studies. In the first section, restatement of some results and discussion of these results are given. In the second section some recommendations for further research studies are made.

5.1. Discussion

Students' spatial ability has been studied by several researchers and educators to investigate its relationship with students' academic achievements and logical thinking abilities; and how to develop students' spatial abilities. In the present study, the effect of type of school on the students' spatial abilities was investigated. Moreover, the relationships between the students' mathematics achievement, logical thinking abilities and their spatial abilities were examined. Lastly, the development of students' spatial abilities with technical drawing course was investigated.

To test the effect of type of school on the students' spatial abilities, one way ANOVA was used. The results showed that there was no statistically significant mean difference among the students who enrolled in different high schools with respect to neither their spatial abilities nor the sub-abilities (spatial visualization ability and spatial orientation ability). One of the reasons for this can be that, when the students' academic achievements are considered, not only their mathematics or science achievements but also their social sciences achievements are considered. Therefore, even though a student has high GPA or high score in high school entrance examination, his/her mathematics achievement will be low. Therefore, investigating the relationship between the students' mathematics achievements and their spatial abilities might be more descriptive.

In our country development of spatial ability is neglected during the elementary and secondary education and when the SAT scores of students are examined, it can be figured out that even the successful students had low spatial ability scores from SAT. Therefore regardless of their achievement in the high school entrance exam, the students had low spatial abilities, so there is not a statistically significant difference between the students' spatial ability with respect to the school type.

Another reason can be that, spatial visualization could be influenced by one's childhood experiences, which were found to be influenced by one's gender, parents' occupations and family income (Robichaux, 2002). These could be valid reasons for explaining the findings of the present study. For instance, subjects of the present study were all from rural area, and they have similar family SES and similar childhood experiences.

Although the mean differences of the students from different schools with respect to their spatial abilities were not statistically significant, there were slight differences. According to the results, the rank of the SAT scores was Anatolian high school, foreign language high school, general high school, commercial vocational high school and industrial vocational high school. When the rank of mean scores of sub-spatial abilities were examined it was seen that the mean scores of students of Anatolian high school and foreign language high school students had the highest scores, where the rank of the students enrolled to other schools changed.

Another purpose of the study was to investigate the relationships between the students' mathematics achievement, logical thinking ability and spatial ability.

The National Council of Teachers of Mathematics recommends five Content Standards (Number and Operation; Patterns, Functions and Algebra; Data Analysis, Statistics, and Probability; Geometry and Spatial Sense; and Measurement) and five Process Standards (Problem solving; Reasoning and Proof; Communication; Connections; and Representations). When the mathematics curriculum of primary and secondary schools in our country are examined, it can be seen that in some concepts spatial ability is very. Spatial ability is mostly important for the geometry and trigonometry concepts in mathematics. Moreover, for the other concepts of mathematics spatial ability is also necessary. As an example in the understanding of the set concept, and in the organization and solution of the set problems, we use Venn-diagrams which are related to spatial abilities. Moreover, transferring the given data in to graphs and charts are also very important for understanding and organizing the given data in problem solving. Also, in the probability concepts we use spatial visual ability, to understand what is given, what is done with the given data and lastly what is asked in the problem.

In the present study, the results also showed that there was a statistically significant relationship between the students' mathematics achievement and their spatial ability. This was consistent with findings of the studies conducted by Battista (1987), Bishop (1980), Hodgson (1996) and Tartre (1990). When the sub-spatial abilities were investigated separately, it was seen that there was also positive relationship between the students' spatial orientation abilities, spatial visualization abilities and mathematics achievements. However, if the Pearson's correlation coefficients were examined, it was seen that the relation between the students' spatial visualization abilities and mathematics achievement was not as strong as the relation between their spatial orientation abilities and mathematics achievement.

Studies also show that spatial ability is related to logical thinking ability also. In the present study to determine logical thinking abilities of the students GALT was used. It contains problems related to identifying and controlling variables, and proportional, correlational, probabilistic and combinatorial reasoning. In identifying and controlling variables, tree-diagrams, Venn-diagrams and charts are used. Moreover, in correlational reasoning, to understand the relations and identify the differences spatial aspects can also be used. In probabilistic reasoning, to understand the problems, visualization of the given data, given sample and the procedure spatial cognition is very important. For the cube comparison test in the SAT combinatorial reasoning is essential. Also for the paper folding test and surface development test in the SAT proportional reasoning is required.

The results of the present study also supported these findings. The results showed that there was a strong positive relationship between the students' spatial ability and their logical thinking ability ($r = 0.49$). Also there was a positive relationship between the students' spatial visualization ability, spatial orientation ability and logical thinking ability. As the previous result, the Pearson's correlation coefficients showed that the relation between the students' spatial orientation ability and logical thinking ability ($r = 0.48$) was stronger then the relation between their spatial visualization ability and logical thinking ability ($r = 0.28$).

Most of the research studies indicated that, there was a positive correlation between spatial training and the students' spatial skill enhancement (Osberg, 1997; Pallascio, Allaire, Mongeau, 1993; Owens & Clements, 1998; Herskowitz, Parzysz, Van Dormolen; 1996; Olkun, 2003; Owens & Clements, 1998). And the research studies showed that technical drawing and spatial abilities were interrelated. In other words, spatial ability was necessary for technical drawing achievement of engineering students (e.g., Ben-Chaim *et al*., 1988; Ben-Chaim *et al*., 1985, Smail, 1983, Alias, Black & Gray, 2002). On the other hand technical drawing activities could be used to develop spatial ability (Olkun, 2003).

In the light of these studies, in the present study the relationship between the students' spatial abilities and their technical drawing achievements was investigated. Furthermore the development of industrial vocational high school students' spatial abilities during the semester they took technical drawing course was examined. The results of the present study were consistent with the previous findings. The sub-spatial abilities were also investigated. It was found that there was a statistically significant relationship between the students' technical drawing achievements and their spatial orientation ability. However, the relationship between the students' technical drawing achievements and their spatial visualization abilities was not statistically significant.

When the relationship between the students' mathematics achievement, logical thinking ability, technical drawing achievement and their spatial visualization ability was examined, it was seen that there was a weak or not a statistically significant correlation. Moreover, when the mean scores of SVAT were examined it was seen that mean score of all the students was, 22.42 over 80 which was too low.

These findings can be explained by the cognitive level of the students. The researchers who dealt with the students' cognitive developments insisted that not only the spatial trainings but also the age and the maturation were important on the development of students' spatial skills (Alias, Black & Gray, 2002; Allyn & Bacon, 1989; Li, 2000). Therefore it can be concluded that, 9^{th} grade students that took SAT were not cognitively mature with respect to their spatial visualization abilities.

The results indicated that there was a positive correlation between the students' spatial abilities and their technical drawing achievements, but to determine whether or not the industrial vocational high school students' spatial abilities developed during the academic year, t-test was used. The results showed that the post-test SAT scores of the students were significantly higher than their pre-test SAT scores. This revealed that the students' spatial abilities developed during the academic year statistically significantly. Moreover for the SVAT scores and the SOAT scores of the industrial vocational high school, a development could also be observed.

As mentioned by the previous research studies, the present study also showed that the students' spatial abilities could be developed. According to the results, technical drawing course may cause the development of students' spatial abilities.

In the light of the previous studies about the importance of cognitive development and the development of spatial ability, the results of the present study can be explained by the students' cognitive maturation. In other words, not only the spatial training of the students by the technical drawing course, but also the students' cognitive development during an academic year can explain the development of students' spatial abilities.

5.2. Recommendations

In this section recommendations are stated for teachers, curriculum developers, teacher educators and researchers in order to develop students' spatial abilities. Currently spatial ability is neglected during elementary and secondary education in our country; therefore high school students' spatial ability levels are very low.

As a result of the study and experience, we can identify what different groups can do for the development of students' spatial abilities as follows;

Teachers should:

- be aware of the importance of spatial ability;
- be aware of the fact that spatial ability can not be taught but can be developed over a period ;

- make the students be aware of the importance of spatial ability;
- prepare concrete activities to develop students spatial abilities during the elementary and secondary education;
- prepare spatial activities with respect to the cognitive levels of students;
- derive activities from the technical drawing activities for the elementary and secondary students;
- enhance the industrial vocational high school students' spatial abilities before the technical drawing course by introductory lessons.

Curriculum developers should:

- syntheses the spatial ability concepts in the elementary and secondary education;
- emphasize that rather than teaching spatial ability as a unit, it should be developed by using activities in other units;
- make authors include concrete activities that helps developing spatial ability in the textbooks;
- give emphasis on the development and use of spatial ability.

Teacher educators should:

- have pre-service teachers be aware of the importance of spatial ability;

- have pre-service teachers qualified on how to develop spatial ability.

In the later studies the following studies can be conducted;

- to investigate the effect of gender differences on the students' spatial abilities;
- to replicate of this study using other grade levels and other school population;
- to understand the effect of technical drawing subjects on students' spatial abilities with an experimental study;
- to investigate the spatial ability of mathematics teachers and pre-service mathematics teachers;
- to investigate the teachers' ways of developing spatial activities.

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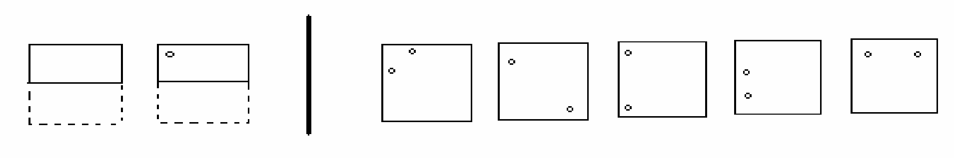
APPENDICES

APPENDIX A

SAMPLE QUESTIONS OF SAT

Paper Folding Test

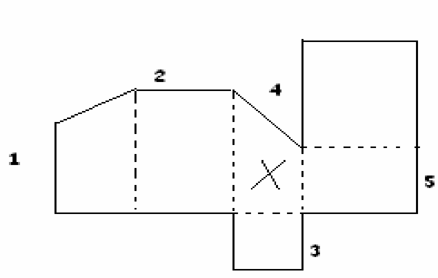
The square shaped paper on the left side of the vertical line is folded and then a hole is made. After unfolding the paper, which one of the shapes in the right side of the vertical line will appear?

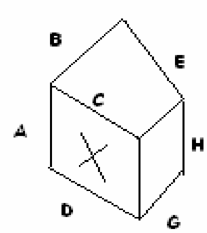


Surface Development Test

When the paper is folded from the dotted lines, the subject on the right will be formed. By imagining the folding of the paper, match the numbered edges to the letters.

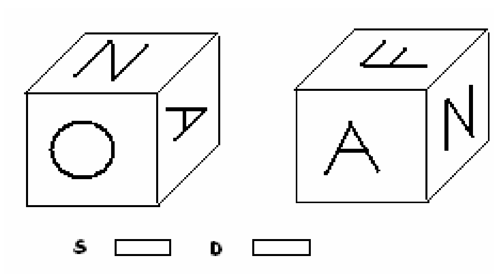
p.c. the surface marked by X on unfolded paper on the left and on the subject on the right shows the same surfaces.





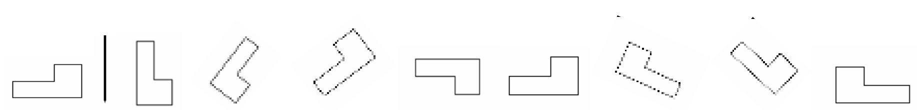
Cube Comparison Test

In the following cubes all the numbers, figures and letters appears only once on each cube, but it can be in an unseen position. Then, find out whether the cubes on the left and the right are the same. If the cubes are the same then mark S (Same), otherwise mark D (Different).



Card Rotation Test

This test requires comparing the shape on the left side of the vertical line with the eight shapes on the right side of the vertical line. Find out whether the shapes on the right side can be determined by rotating the shape on the left side of the vertical line, in other words examine whether the shapes are the same or different. If the shapes are the same as the shape on the left side of the vertical line then mark S (Same), otherwise mark D (Different).



S D S D S D S D S D S D S D S D

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APPENDIX B

B.E.M.L. TEKNİK RESİM DERSİ 9. SINIF ÜNİTELENDİRİLMİŞ YILLIK DERS PLANI

AY	DERS SAATİ	HEDEF VE DAVRANIŞLAR	KONULAR	KULLANILAN EĞİTİM TEKNOLOJİLERİ, ARAÇ VE GEREÇLERİ
EYLÜL	4	Teknik Resmin endüstriyel alandaki yeri ve önemini kavrar	A-Teknik Resmin Tanımı B-Teknik Resmin Meslek Resimle ilgisi C-Teknik Resmin Endüstrideki yeri ve önemi 1-Teknik bir haberleşme dili olarak 2-Standardizasyona sağ.yarar bakımından	Teknik Resim çizim takımları Teknik Resim kitabi(Hamdi Özkara) Örnek Çizim ve Levhalar Öğretmen ders notları
	4	Teknik Resim çiziminde kullanılan aletleri tanır ve tekniğine uygun kullanır	A-Resim aletlerinin çeşitleri 1-Kurşun kalem ve çeşitleri 2-Silgi ve çeşitleri 3-Cetveller 4-Gönyeler 5-Pergel ve takımları B-Resim aletlerinin kullanılması ve bakımı	Teknik Resim çizim takımları Teknik Resim kitabı. Örnek Çizim ve Levhalar Öğretmen ders notları
	4	Resim çizimlerinde kullanılan standart resim kağıtlarını tanır özelliklerini ve kullanımlarını kavrar.	A-Resim kağıdı çeşitleri B-Resim kağıdı ölçüleri C-Yazı alanı(Antetler)	Teknik Resim çizim takımları Teknik Resim kitabı. Örnek Çizim ve Levhalar Öğretmen ders notları
EKİM	4	Teknik resimde kullanılan ölçekleri açıklar gerçek ölçeği bilir.Örnek uygulamalar yapar	A-Tanımı ve önemi B-Ölçek çeşitleri 1-Gerçek ölçekler 1/1	Teknik Resim çizim takımları Teknik Resim kitabı Örnek Çizim ve Levhalar Öğretmen ders notları
	4	Küçültme ve büyültme ölçeklerini kavrar.Örnek uygulamalar yapar	2-Küçültme Ölçeği 1/ 2,5 –1/5 –1/10 –1/20 3-Büyültme Ölçekleri 2/1-5/1-10/1	Teknik Resim çizim takımları Teknik Resim kitabı. Örnek Çizim ve Levhalar Öğretmen ders notları
	4	Standart yazının önemini kavrar. Ölçülerini çeşitlerini ve kullanımı Öğrenir	A-YAZILAR 1-Standart biçimleri 2-Ölçüleri 3-Çeşitleri	Teknik Resim çizim takımları Teknik Resim kitabı. Örnek Çizim ve Levhalar Öğretmen ders notları
	4	Standart rakam kullanmanın önemini kavrar.Rakam ve yazıları Çizimlerinde kullanmayı kavrar.	B-Rakamlar 1-Standart biçimleri 2-Dik ve Eğik a-Romen rakamları b-Latin rakamları C-Rakam ve yazı ile ilgili uygulamalar	Teknik Resim çizim takımları Teknik Resim kitabı. Örnek Çizim ve Levhalar Öğretmen ders notları
	4	Çizginin çizimdeki önemini kavrar Kullanıldığı yerleri öğrenir. Çizimlerinde çizgi çeşitlerini kullanır.	A-Çizginin Çizimdeki önemi B-Çizgi Ölçüleri C-Çizgi çeşitleri ve kullanıldığı yerler 1-Sürekli kalın çizgi 2-Sürekli ince çizgi 3-Kesik,orta çizgi	Teknik Resim çizim takımları Teknik Resim kitabi.Örnek Çizim ve Levhalar ders notları

KASIM	4	Çizginin çizimdeki önemini kavrar Kullanıldığı yerleri öğrenir. Çizimlerinde çizgi çeşitlerini kullanır	4-Noktalı kesik çizgi 5-Noktalı Kesik ince uçları kalın çizgi 6-Noktalı kesik kalın çizgi	Teknik Resim çizim takımları Teknik Resim kitabı Örnek Çizim ve Levhalar Öğretmen ders notları
	4	Çemberleri çeşitli ölçülerde bölmeyi öğrenir. Üçgen ve Dörtgen çizim metotlarını öğrenir	A-Çemberlerin 3,4,5 ve 6'ya bölünmesi B-Çokgenlerin çizimi 1-Üçgen 2-Dörtgen	Teknik Resim çizim takımları Teknik Resim kitabı. Örnek Çizim ve Levhalar Öğretmen ders notları
	4	Beşgen ve altıgen çizim metotlarını öğrenir. Basit saç çizimleri yapar.	3-Beşgen 4-Altıgen C-Çeşitli çember yaylardan ve doğru çizgilerden oluşan saç parçaların çizimi	Teknik Resim çizim takımları Teknik Resim kitabı. Örnek Çizim ve Levhalar Öğretmen ders notları
	4	İzdüşüm ile ilgili temel ilkeleri kavrar.Çeşitlerini öğrenir.	A-İzdüşümün genel tanımı 1-Merkezi (Konik)izdüşüm 2-Paralel izdüşüm a-Eğik izdüşüm b-Dik izdüşüm	Teknik Resim çizim takımları Teknik Resim kitabı. Örnek Çizim ve Levhalar Öğretmen ders notları
ARALIK	4	İzdüşüm düzlemlerini tanır.Özelliklerini kavrar.	B-İzdüşüm Düzlemleri Tanımı ve Çeşitleri 1-Düşey Düzlem 2-Yatay Düzlem 3-Yanal Düzlem	Teknik Resim çizim takımları Teknik Resim kitabı. Örnek Çizim ve Levhalar Öğretmen ders notları
	4	Örnek parçalardan görünüş çıkarmasını kavrar.	C-Görünüş tanımı ve çeşitleri 1-Ön görünüş 2-Üst görünüş 3-Sol yan görünüş 4-Diğer görünüşler a-Sağ yan görünüş b-Alttan görünüş c-Arkadan görünüş	Teknik Resim çizim takımları Teknik Resim kitabı. Örnek Çizim ve Levhalar Öğretmen ders notları
	4	Nokta,doğru parçası ve düzlemlerin İzdüşümlerini çizer.	D-Nokta,Doğru parçası ve Düzlemlerin izdüşümlerinin çizimi	Teknik Resim çizim takımları Teknik Resim kitabı. Örnek Çizim ve Levhalar Öğretmen ders notları
	4	Doğru parçalarının ve düzlemlerin gerçek büyüklüklerini bulur Bunun metotlarını kavrar.	E-Doğru parçalarının ,Düzlemlerin gerçek büyüklüklerinin bulma metotlarını tanıma Ve çizgileri 1-Yardımcı izdüşüm metodu 2-Döndürme metodu 3-Yatırma metodu	Teknik Resim çizim takımları Teknik Resim kitabı. Örnek Çizim ve Levhalar Öğretmen ders notları
OCAK	4	Örnek parçalardan görünüş çıkarmasını kavrar. Kare ve silindirik parçaları tek görünüşle ifade eder. Ölçekli çizmeyi öğrenir.	A-Görünüş çıkarmak için; 1-Parça konumunun tespiti 2-Görünüş çeşitleri ve sayısı tespiti 3-Ölçek tespiti B-Tek görünüşle ifade edilen parçaların çizimi C-Kare ve silindirik parçaların O işareti ile tek görünüşle ifadesinin açıklanması çizimi	Teknik Resim çizim takımları Teknik Resim kitabı. Örnek Çizim ve Levhalar Öğretmen ders notları
	4	İki görünüşü farklı fakat üçüncü görünüşü ortak olabilecek parçaların görünüşlerini çizer	D-İki ve üç görünüşlü parçaların çizimi E-İki görünüşe göre üçüncü görünüşleri ortak olabilen parçaların ortak görünüşlerini çıkarma ve çizme	Teknik Resim çizim takımları Teknik Resim kitabı. Örnek Çizim ve Levhalar Öğretmen ders notları

ŞUBAT	4	Eksik verilen görünüşleri tamamlama metotlarını öğrenir.	G-Eksik verilen görünüşlerin tamamlanması H-Yardımcı görünüşlere ihtiyaç duyulan uygun parçaların seçimi	Teknik Resim çizim takımları Teknik Resim kitabı. Örnek Çizim ve Levhalar Öğretmen ders notları
	4	Eksik verilen görünüşleri tamamlama metotlarını öğrenir	G-Eksik verilen görünüşlerin tamamlanması H-Yardımcı görünüşlere ihtiyaç duyulan uygun parçaların seçimi	Teknik Resim çizim takımları Teknik Resim kitabı. Örnek Çizim ve Levhalar Öğretmen ders notları
	4	Perspektifi tanımlar.Çeşitlerinden İzometrik perspektifin özelliklerini öğrenir.Örnek çizimler yapar.	A-Perspektifin tanımı ve çeşitleri 1-Aksonometrik perspektif a-İzometrik perspektif	Teknik Resim çizim takımları Teknik Resim kitabı. Örnek Çizim ve Levhalar Öğretmen ders notları
MART	4	Dimetrik ve trimetrik perspektif çeşitlerinin özelliklerini öğrenir. Örnek çizimler yapar.	b-Dimetrik perspektif c-Trimetrik perspektif	Teknik Resim çizim takımları Teknik Resim kitabı. Örnek Çizim ve Levhalar Öğretmen ders notları
	4	Eğik ve konik perspektif çeşitlerinin özelliklerini bilir. Örnek çizimler yapar.	2-Eğik perspektif 3-Konik(Merkezi)perspektif	Teknik Resim çizim takımları Teknik Resim kitabı. Örnek Çizim ve Levhalar Öğretmen ders notları
	4	Basit geometrik şekilleri izometrik Dimetrik ve eğik çizerek aralarındaki farkı görür.	B-Basit geometrik cisimlerin izometrik dimetrik ve eğik perspektiflerinin çizimi	Teknik Resim çizim takımları Teknik Resim kitabı. Örnek Çizim ve Levhalar Öğretmen ders notları
	4	Kesit almanın amacını kavrar. Tam kesit almayı öğrenir.	A-Kesit almanın tanımı,önemi ve çeşitleri 1-Tam kesit	Teknik Resim çizim takımları Teknik Resim kitabı. Örnek Çizim ve Levhalar Öğretmen ders notları
NİSAN	4	Yarım ve kısmi kesit almayı kavrar.	2-Yarım kesit 3-Bölgesel/kısmi)kesit	Teknik Resim çizim takımları Teknik Resim kitabı Örnek Çizim ve Levhalar Öğretmen ders notları
	4	Kademeli ve döndürülmüş kesit almayı öğrenir.	4-Kademeli kesit 5-Döndürülmüş kesit	Teknik Resim çiz.tk. Teknik Resim kitabı Örnek modeller
	4	Tarama çizgilerinin özelliklerini öğrenir	B-Kesit yüzeylerin taranması 1-Tarama çizgileri 2-Tarama açıları 3-Tarama yönleri	Teknik Resim çizim takımları Teknik Resim kitabı. Örnek Çizim ve Levhalar Öğretmen ders notları
	4	Çeşitli basit resimlerin kesitlerini almayı kavrar. Kesit alınmış resimleri analiz eder.	C-Kesitlerle ilgili çizimlerin uygulanması	Teknik Resim çizim takımları Teknik Resim kitabı. Örnek Çizim ve Levhalar Öğretmen ders notları

NİSAN	4	Çeşitli basit resimlerin kesitlerini almayı kavrar. Kesit alınmış resimleri analiz eder.	C-Kesitlerle ilgili çizimlerin uygulanması	Teknik Resim çizim takımları Teknik Resim kitabı Örnek Çizim ve Levhalar Öğretmen ders notları
MAYIS	4	Ölçümlendirmenin amacını kavrar. Ölçümlendirme kurallarını öğrenir. Ölçü elemanlarının özelliklerini kavrar	A-Ölçümlendirmenin gereği ve önemi B-Ölçümlendirme kuralları C-Ölçümlendirme elemanları 1-Ölçü sınır çizgisi 2-Ölçü çizgisi 3-Ölçü okları biçimi ve ölçüsü 4-Ölçü rakamları	Teknik Resim çizim takımları Teknik Resim kitabı Örnek Çizim ve Levhalar Öğretmen ders notları
	4	Amacına uygun ölçümlendirme yapar	D-Ölçülerin resim üzerine dağılışı E-Resimlere gereği ve yeteri miktarda ölçü verme,gereksiz ölçümlendirmeden kaçınma Önemi F-Ölçümlendirme uygulaması yapılması	Teknik Resim çizim takımları Teknik Resim kitabı Örnek Çizim ve Levhalar Öğretmen ders notları
	4	Yüzey işleme işaretlerinin önemini kavrar.Pürüzlüğün özelliklerini öğrenir.	A-Yüzey işleme işaretlerinin tanımı ve önemi B-Talaş kaldırılmayan ve kaldırılan yüzeylerin kalitelerinde kullanılan işaretlerin önemi C-Pürüzlük tanımı 1-Pürüzlüğün sınıflandırılması 2-Pürüzlük değerleri	Teknik Resim çizim takımları Teknik Resim kitabı Örnek Çizim ve Levhalar Öğretmen ders notları
	4	Resimde okumayı öğrenir. Örnek çizimler yapar.	D-Yüzey işleme yönlerinin gösterilmesi E-Yüzey kalite işleme ve pürüzlülüğün resimler üzerinde gösterilmesi F-Özel işlem görmüş yüzeylerin resimlerde gösterilmesi	Teknik Resim çizim takımları Teknik Resim kitabı Örnek Çizim ve Levhalar Öğretmen ders notları
	4	Toleransın tanımını yapar. Tolerans gerektiren nedenleri öğrenir.	A-Toleransın tanımı önemi B-Tolerans gerektiren nedenler 1-Yapımında makine ve avadanlık hataları 2-Ölçü aleti hataları 3-Isı ve ışık hataları 4-Kişisel hatalar	Teknik Resim çizim takımları Teknik Resim kitabı Örnek Çizim ve Levhalar Öğretmen ders notları
HAZİRAN	4	Toleransları resim üzerinde okur gösterir.	C-Genel kavramlar 1-Anma ölçüleri 2-Sınır ölçüleri 3-Tolerans ve işleme toleransı 4-Tolerans sembollerinin tanımı D-Tolerans çizgilerinin okunması E-Tolerans resimlerinin gösterilmesi	Teknik Resim çizim takımları Teknik Resim kitabı Örnek Çizim ve Levhalar Öğretmen ders notları