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ABSTRACT

This study investigates children's spatial cognition in the microcomputer environment created by "HyperGami." Two categories of spatial cognition have been described: spatial visualization, which involves mentally rotating, manipulating and twisting two- and three-dimensional objects; and spatial orientation, which involves the ability to remain unconfused by changing orientations of spatial configurations. "HyperGami" is a computer application which allows students to design, decorate, explore, and manipulate a two-dimensional net made up of polygons and their associated three-dimensional solids. Subjects for this study were 12 sixth- through ninth-grade students in the University of Wyoming Laboratory School. Students were given pretests and posttests. Once a week for a period of 6 weeks, the subjects interacted individually with "HyperGami" for 1 hour. They were divided into three groups, each with different exploration exercises and different aims. In the first group, each subject made gains in their ability to recognize the nets of solids, which require spatial visualization ability. Results from the second group suggest that interaction with "HyperGami" may have helped the subjects improve their ability to visualize the solid from its two-dimensional net. No evidence was found in the third group to show that the hours spent interacting with HyperGami helped the children to count vertices, to count faces, or to identify faces after truncation of vertices. Appendices present the polygon configurations used in the pretest and posttest. (Contains 31 references.) (AEF)

Exploring Children's Spatial Visual Thinking In An HyperGami Environment

Patricia McClurg, Jung Lee, Maria Shavalier & Kermit Jacobsen

Abstract

The purpose of this study is to investigate children's spatial cognition in the microcomputer environment created by HyperGami. The results of exploratory study suggest that HyperGami is a rich environment for developing spatial visual thinking skills.

Introduction

Can computer environments nurture spatial visual thinking? From a constructivist perspective, spatial cognition develops in the course of active involvement with the environment by the child who must assimilate and accommodate experiences into existing schemata (Piaget & Inhelder, 1956). Papert used the computer as a medium to pioneer such an environment when he created LOGO - which he described as a microworld where students can formulate and test theories (Papert,1980). Numerous programs now purport to be microworlds which users can visit and explore. But, could such an environment nurture spatial visual thinking?

Clark (1983) cautioned against over generalizing the effect of the computer (or any medium) on instruction and stated that "the best current evidence is that media are mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition."(p.445). Clark called for a new theoretical model to guide technology research. A decade later Kozma (1991) outlined a framework which builds on the idea that the learner actively collaborates with the medium to construct knowledge rather than having the learning "delivered" via some medium. Kozma argues that each medium has unique characteristics in terms of how it is used, the symbol systems employed and the cognitive processing capabilities required and states that "ultimately, our ability to take advantage of emerging technologies will depend upon the creativity of their designers, their ability to exploit the capabilities of the media, and our understanding of the relationship between these capabilities and learning"(p.206).

The explorations reported in this paper investigate children's spatial cognition in the microcomputer environment created by HyperGami.

Why Spatial Visual Thinking?

As early as 1957, the U.S. Employment Service listed performance on spatial ability tasks as a predictor for success in occupations including all classes of engineers and draftsmen, architects, cartoonists, mathematicians, scientists, an virtually all medical personnel. Studies followed which demonstrated high correlation between performance on spatial ability measures and success in art (McWhinnie, 1994), science (Pallrand & Seeber, 1984; Gimmestad, 1984; Pribyl &Bodner, 1987), and mathematics (Battista, 1990; Fennema & Sherman, 1977; Guay & McDaniel 1977).

Studies of the brain and cognition have resulted in calls for educators to recognize and nurture "multiple intelligences" (Denkla, 1991; Gardner, 1993; Lazearz, 1994). Spatial visual thinking is an area of cognition which often receives little formal attention in our school systems. The computer is a medium with capabilities for creating dynamic microworld environments where children have control over actions and can formulate and test theories and strategies which require coordination of horizontal and vertical axes as well as mental manipulation and rotation of objects through space. In fact some evidence exists that many computer applications require some degree of spatial cognition. Norman (1994) thought that computer-based technology might amplify individual differences and tried to find the major sources driving differences in performance. He described a high correlation between spatial visualization ability and computer performance. Vicente, Hayes, and Williges

(1987) supported Norman's theory. They investigated 21 predictors of performance in finding information in a computerized database. Only spatial ability and vocabulary accounted for significant unique portions of the variance. Moreover, the spatial ability predictor was the most influential.

What is Spatial Cognition?

Various classification schemes have been used to describe components of spatial visual thinking. After an extensive review of studies relating to human spatial abilities McGee (1979) described two categories of spatial cognition. These are spatial visualization and spatial orientation. Spatial visualization involves mentally rotating, manipulating and twisting two and three dimensional stimulus objects. Spatial orientation with respect to one's own body involves the ability to remain unconfused by changing orientations of spatial configurations. According to John Eliot and Ian Macfarlane Smith (1983), spatial ability refers to "... the perception and retention of visual forms and the mental manipulation and reconstruction of visual shapes" (p. 12). A similar definition is found in Linn and Peterson (1983). They defined "spatial ability as representing, transforming, generating, and recalling non-linguistic information" (Linn & Peterson, 1983). Spatial ability has been thought of as a domain of abilities rather than a single ability or skill (Pellegrino & Hunt, 1991). Spatial ability is generally identified as having three major factors: spatial perception, mental rotation, and spatial visualization (Linn & Petersen, 1985). Spatial perception is an ability "to determine spatial relationships with respect to the orientation of their own bodies, in spite of distracting information" (Linn & Petersen, 1985, p. 5). Mental rotation is the ability "to rotate a two or three dimensional figure rapidly and accurately" (Linn & Petersen, 1985, p. 7). Spatial visualization is a more complex ability than the other two major factors. Spatial visualization refers to spatial ability tasks that "involve complicated multi-step manipulation of spatially presented information" (Linn & Peterson, 1985. p.9).

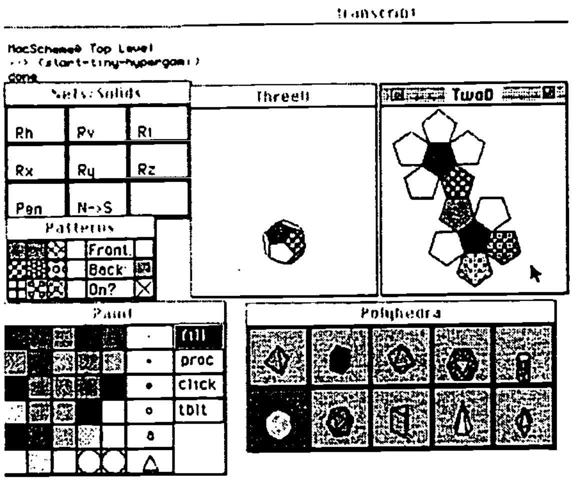
Ongoing research efforts suggest that students' performance on spatial ability measures can be improved by practice or training. Piaget and Inhelder (1956) said children's spatial cognition develops when they are actively involved with the environment so that they assimilate and accommodate new experiences into their existing knowledge. Ben-Chaim et al (1989) found from their research that suitable intervention has great success for improving spatial visualization. They suggested that "spatial visualization training, in particular concrete experiences, should be a part of the middle school curriculum". Brinkmann (1966) found that a complex spatial test is substantially improved after training in geometry that was directed to emphasize visual/imaginable aspects of geometry. However, simply learning geometry focusing on logical proofs has no impact on spatial ability according to Brown (1954).

McClurg and Chaille (1987) and McClurg (1992) investigated the effects of computer games utilizing spatial skills on the development of spatial ability. Both studies found that males and females improved their scores on a spatial ability measure after playing with computer software. McClurg and Chaille (1987) stated that in order for a computer game to encourage spatial cognition, it must provide an environment where children are active participants. Norman(1994) also reported that computer interfaces allow the user to perform spatial and intermediate operations on the interface rather than in the head are among the most favorable designs for developing spatial ability.

HyperGami

A recent computer application called HyperGami (Eigenberg & Nishioka, 1995) allows students to design, decorate, explore, and manipulate a two-dimensional net made up of polygons and the associated three-dimensional solid. A "net" is the shape that would result when all the sides of a polyhedron are unfolded. A "solid" is the shape of three dimensional polyhedron. The program allows students to view various kinds of polyhedra, and to select one. When the polyhedron has been selected, a "3-D" picture of the polyhedron appears on the screen as well as a 2-dimensional folding net (Figure 1).

Figure 1
HyperGami Window



Thus students can see how the three dimensional object can be unfolded and vice versa. Students have various methods available to decorate the net. They can fill each polygon with a solid color or make patterns with color. Students can also write and make their own designs on the folding net. Hence the degree of sophistication with which a student decorates the folding net depends on both the student's interest and ability (Eigenberg & Nishioka, 1995). Students print out the polyhedra they created on paper, cut and fold to make solid, beautiful "objets d'art". The act of exploring the nets of many kinds of solids and then having opportunities to fold these nets into various complex geometric solids is in alliance with the constructivist perspective, i.e. that spatial cognition develops in the course of active involvement with the environment by the child. Eigenberg and Nishioka (1995) believe that students can best understand three-dimensional geometry by actually holding and manipulating shapes. HyperGami provides an environment in which students are actively involved since they manipulate computer generated graphics physically as well as mentally.

The importance of polyhedra as a means of developing spatial ability as well as developing mathematical skills has been studied. Early in 1948, Piaget and Inhelder stated the importance of the development of geometric concepts in children. They found that the child who is familiar with folding and unfolding paper shapes through his work at school had much better performance in imagining and drawing the nets of simple shapes than children who lacked this experience. Peterson (1988) emphasized polyhedral models as a motivational value. He said polyhedral models can act not only as tangible mathematical diagrams, but also as objects having artistic and motivational value.

HyperGami allows students to have experiences with nets and solids mentally and manually. These activities are related to spatial visualization ability. The folding or unfolding of flat patterns and imagining objects and changes to objects in space requires spatial visual thinking. HyperGami provides an environment for users to improve spatial visualization ability among three major areas of spatial ability. The explorations reported in this paper investigated students' spatial visual thinking while working with HyperGami.

Methods and Measurement

A sample size of twelve subjects was used for this exploratory study. The subjects were students in the University of Wyoming Laboratory School and the grade levels included sixth through ninth grade. There were seven boys and five girls and they all had volunteered for this study as an elective course. The subjects were divided into three groups. Each group was led by one of three investigators. Each group was given a pretest and a posttest designed to examine students' spatial visualization thinking. Every Friday over a period of 6 weeks, subjects interacted with HyperGami for one hour. During the sessions subjects selected polyhedra and decorated the nets with different colors and patterns. While subjects decorated the net, they could observe its solid on the same screen. Subjects also folded the polyhedra. Subjects started with simple polyhedra such as the tetrahedron and cube and later tried more complicated ones such as the archimidean solids. Subjects also explored truncation of some polyhedra. A description contrasting procedures used in each of the explorations is included below.

Exploration 1

The students in this study were two sixth grade boys and two sixth grade girls. The students were given a pretest and an identical posttest and the results of the tests were compared. A variety of geometric solids were placed on the table. Students were given five minutes in which to examine the solids. Then only ten of the solids were placed on a table in a line. Students were given a paper on which was exhibited the folding nets of these solids along with several patterns involving polygons that were similar in appearance to the folding nets. The polyhedra whose nets were pictured on the paper were the cube, tetrahedron, cubeoctohedron, octohedron, three-sided prism, ten-sided antiprism, dodecohedron, and icosohedron. A six-sided and a ten-sided prism were in the line on the table also but their nets were not pictured on the paper. (See Appendix A). Students were asked to match the solids with their folding nets on the paper without manipulating the solids.

On the test there were two types of correct and two types of incorrect responses. If the student correctly matched the solid with its net it was called a correct match. If they recognized that the six and ten-sided prisms' nets were not pictured, it was considered a correct nonmatch. Conversely, if they incorrectly matched a solid with the wrong net, it was an incorrect match. If they matched a six or ten-sided prism with a net, that was an incorrect nonmatch. If they did not assign a net to any solid whose net was pictured, it was also considered an incorrect nonmatch. The results of the pretest and the posttest are summarized in Figure 2.

Figure 2
Pretest and Posttest

# possible	8	2						
	Pretest				Posttest			
	Correct		Incorrect		Correct		Incorrect	
Subject	M	NM	M	NM	M	NM	M	NM
A	2	0	6	2	3	0	5	3
B	5	1	1	3	5	2	1	2
C	5	0	3	2	5	2	1	2
D	5	2	1	1				

As is shown the total number of correct answers increased for all the subjects who took the posttest. (Subject D was absent the day of the posttest). In particular, subjects B and C recognized that the two prisms' nets were not pictured. On the posttest, subject A correctly matched the cubeoctohedron and subject C correctly matched the dodecohedron. They had not matched them correctly on the pretest. However on the posttest, subject A again tried to find a match for all the polyhedra and subject B made an incorrect match for a match that was correct on the pretest. However, the number of correct scores increased for all. In particular, since two of the students recognized that two of the patterns were not there, this may indicate growth in their spatial visual thinking.

Exploration 2

HyperGami provides an environment which engages students in spatial visual thinking. Additionally, the user must manually manipulate the nets to produce a 3-D "hard" copy. Users cut, fold, and glue nets to make solids with their hands. This exploration investigated students' spatial visual thinking and examined the possible role of manual dexterity as students interacted with activities in HyperGami.

The subjects in this study were a sixth grade boy, a seventh grade girl, a seventh grade boy, and a ninth grade boy. Performances of pretest and posttest were compared. In pretest and posttest, subjects were given two nets on paper, a cube and a complex net (Appendix B). Before folding each net, the subjects were asked to predict the three dimensional shape the nets would become. All subjects recognized the cube from the net. For the cubeoctohedron, they said that they had no idea. Subject A who finished first said, "I can imagine the shape".

Subjects were then asked to fold the nets. While they were folding each net, an investigator measured the amount of time the subjects spent and observed their behaviors. Figure 3 summarizes the results.

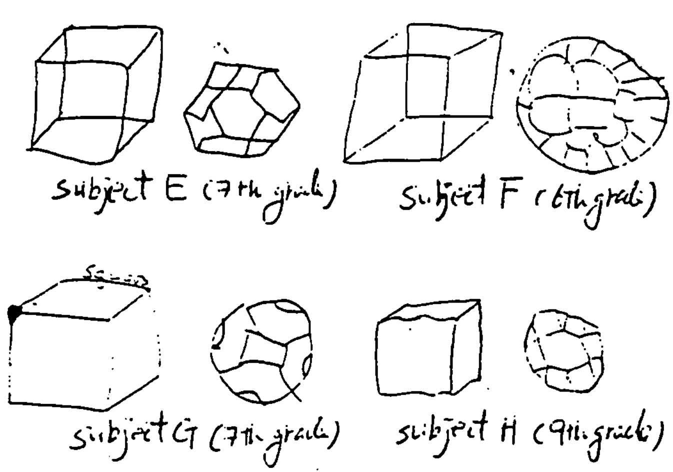
Figure 3
The amount of time to fold each net (in minutes)

	Cube Net		Complex Net	
Subject	Pre	Post	Pre	Post
E	2	1.83	5.17	4.5
F	2	1.83	5.5	4.08
G	2	1.83	5.5	4.5
H	2	2	6	unfinished

In the pretest, subjects spent about 2 minutes to fold the cube. In the given 5 minutes, none of them had finished folding the complex net called "cubeoctohedron". Subject E finished just after 5 minutes. Subject H didn't know how to start folding it. He folded and unfolded the piece of paper for more than 2 minutes. Since the test was a group activity, subject H was eventually able to complete the construction by observing other students' responses.

In the posttest, the cube net was used again. However a different and more complex net called "Posttest Complex Net" replaced the cubeoctohedron . The subjects had never seen the Posttest Complex Net during sessions. Before folding the nets, subjects were asked to predict and draw the shape of its solid. All subjects drew the cube quite accurately, however, when they drew the Posttest Complex Net, their drawings were varied and represented three different levels of visualization (Figure 4).

Figure 4
Students' drawings



Even though they are not accurate, Subject E and H's drawing have squares and hexagons, and the connections are linear. Subject H drawing has squares and rather linear compared with Subject F. Subject F's drawing was global and nonlinear. When considering their response, "no idea", in the pretest, these drawings indicate that they could imagine some shapes from the net.

The amount of time to fold the cube on the posttest was slightly reduced from that on the pretest. However, folding the Posttest Complex Net took much less time than folding cubeoctohedron on the pretest for three students. Subject F finished in about 4 minutes, and subject E and G finished in about 5 minutes. Subject H couldn't finish in the given 5 minutes. He said, "I couldn't fold this, this is too complicated."

Since the pre and post test measure for this exploration was timed, subjects' performance was examined for evidence of spatial visual thinking as well as the manual dexterity required to fold the nets. By drawing a prediction of the resulting shape, students were revealing their initial representation of the projected 3-D object. The differences in manual dexterity among subjects and also the differences between pre and posttest of each subject could be measured by the amount of time for folding the cube. The fact that subjects all spent about 2 minutes for folding the cube indicate that there was little variability in manual dexterity among the subjects. Also the amount of time for folding the cube didn't change much from the pretest to the posttest. The small differences might be caused by folding same net twice. Therefore, it is not evident that students' manual dexterity effected the results or changed substantially after students had used HyperGami for 6 hours.

However, there were noticeable time differences for folding the complex nets among subjects, and between the pre and posttest. Three subjects spent less time for folding the complex net on the posttest. When considering that the Posttest Complex Net was more complex than any with which they had worked, we suggest that the time difference between the pre and posttest is even more meaningful. These preliminary results suggest that HyperGami is a rich environment for developing spatial visual thinking skills.

Exploration 3

Four sixth grade students, three boys and one girl, participated in this exploration. Subjects were asked to count the vertices and faces and to identify the shape of the faces after truncation of vertices in the pre and posttest.

Students were given approximately five minutes to examine tetrahedrons, cubes, and octahedrons. The investigator identified the vertices on each of the polyhedra. The types of faces on each of the polyhedra were also noted by the investigator. Instruction was given on how truncation was done; each vertex would be shaved off to an equal depth. After examination by each student, the polyhedra were removed and the test was given.

The results of the pre and posttest are summarized in Figure 5. The results show no evidence of improvement between pre and posttest. The students in this exploration did not seem to have the knowledge and experiential background necessary for abstract reasoning problems dealing with truncation. It would be beneficial to investigate these activities with subjects at the high school or college level.

Figure 5
Pre and Posttest Results

	Vertices and Faces Counted		Faces Formed by Truncation	
subj.	Pre	Post	Pre	Post
I	6	6	5	5
J	3	3	0	0
K	5	4	3	1
L	5	5	2	6

Discussion

Each of our explorations examined users interactions with a potential rich environment for developing spatial visual thinking skills. In the first exploration each subject made gains in their ability to recognize the nets of solids. This requires spatial visualization ability. However, the ability to recognize more of the complicated nets should have increased if they were given more time in which to explore with the HyperGami.

Students in the second exploration reduced time for folding the complex net. The result suggests that interaction with HyperGami may have helped the subjects improve their ability to visualize the solid from its two dimensional net. Subjects reported that "HyperGami helped their imagination ..." to look at three dimensional polyhedra from two dimensional nets and vice versa. No evidence was found that manual dexterity was a confounding variable.

The subjects' drawings support the findings of Potari and Spiliotpoulou (1992). They found that the degree of sophistication in visualizing the nets grew with respect to the age of the children. Younger children had a more global and holistic view of the solids' nets and older children viewed the nets in a quantitative and analytic manner. Subject F was the youngest among the four subjects. Subject F's drawings are the most global and holistic. Even though Subject H, the oldest, could not finish folding, his drawing shows that he identified a hexagon and squares in his imagined solid.

Counting vertices and counting faces without seeing the object requires spatial visual thinking. However, we found no evidence in our third exploration to show that the six hours spent interacting with HyperGami helped the sixth graders to count vertices, to count faces or to identify faces after truncation of vertices. Further study in this area is needed. Also, the use of older subjects may be considered.

More work needs to be done using HyperGami[1] and perhaps other software similar to HyperGami before any generalizations can be made.. In our investigation, we were only able to work for one hour a week during a period of six weeks and we were limited to four children in each group. Studies need to be done with larger groups of children and in a situation in which the children have more time to work within the microenvironment.

The results of this exploratory study were promising. Further study aimed at identifying the cognitive processes involved as students interact with this media is warranted.

[1] At the time we conducted our investigation, Fall 1995, HyperGami was still in development. The beta version requires a Macintosh with at least 10 megabytes of RAM. As a result if one was using a machine without much more than 10M of memory, many of the processes, including truncation, in the program were extremely slow.

References

Arvold, B. (1993). The study of the unknown: Taking geometry to new dimensions. The Mathematics Educator, 4(1), 17-20

Battista, M. T. (1990). Spatial visualization and gender differences in high school geometry. Journal for Research in Mathematics Education 21(1) 47-60

Ben-Chaim, D., Lappan, G. & Houang, R. T. (1989). Adolescents' ability to communicate spatial information: analyzing and effecting students' performance. Educational Studies in Mathematics, 20(2).

Brinkman, E. H. (1966). Programmed instruction as a technique for improving spatial visualization. Journal of Applied Psychology, 50, 172-184

Brown, R. R. (1954). The effect of an experimental course in geometry on ability to visualize in three dimentions. doctoral dissertation, University of Illinois.

Clark, .R.E. (1983). Reconsidering research on learning from media. Review of Education Research, 53(4).

Denkla.,M. (1991). The brain and learning-knowledge differences: the value and the caution. Keynote speech given at The art and scienc of learning conference sponsored by the U.S. Office of Educational Research and Improvement, Washington, D.C., January.

Eigenberg, M. & Nishioka, A. (1995). Creating polyhedral models by computer

Eliot, J. & Smith I. M. (1983). An International Directory of Spatial Tests. Atlantic Highland, NJ:NFER-NELSON Pub.

Fennema, E. & Sherman, J. (1977). Sex-related differences in mathematics achievement, spatial visualization and socioculture factors. American Educational Research Journal, 14, 51-71.

Fredette, B. W. (1995). What is the relationship between artistic performance and visual proficiency? Imagery and Visual Literacy. International Visual Literacy Association Readings, 394-401

Gardner,H. (1993). The Theory in Practice. New York: Basic Books, Incorporated, Publishers.

Gimmestad,B. (1984) Sex differences in spatial visualization; Implications for the mathematics teacher. Paper presented at Annual Meeting of the National Council of Teachers of Mathematics Association, San Francisco.

Guay, R. B. & McDaniel, E. (1977). The relationship between mathematics achievement and spatial abilities among elementary school children. Journal for Research in Mathematics Education, 8(3), 211-215.

Kozma,R. (1991). Learning with media. Review of Educational Research, 61(2).

Lazear, D. (1994). Seven ways of knowing: Teaching for multiple intelligences. Palatine, IL: Sklight Publishing.

Linn, M. C. & Peterson, A. C. (1985). Emergence and characterization of sex differences in spatial ability: A meta-analysis. Child Development, 56. 1479-1498

McClurg, P. A. (1992). Investigating the development of spatial cognition in problem-solving microworlds. Journal of Computing in Childhood Education,

McClurg, P. A. & Chiristine C. (1987). Computer games: Environments for developing spatial cognition? Journal of Educational Computing Research, 3(1), 95-111

McGee,M. (1979). Human spatial abilities: Psychometric studies and environmental, genetic, hormonal and neurological influences, Psychological Bulletin 86(5).

McWhinne, H. J. (1994). Art students and their educational needs. NAEA Conference. Baltimore, MD

Norman, K. L (1994). Spatial visualization - A gateway to computer-based technology. Journal of Special Education Technology, 12(3). 195-206

Pallrand,G.J. & Seeber,F. (1984). Spatial ability and achievement in introductory physics. Journal of Research in Science Teaching, 21(5).

Papert, S. (1993). The Children's Machine. New York: Basic Books.

Papert, S. (1980). Mindstorms. New York: Basic Books.

Pellegrino, J. W. & Hunt, E. B. (1991). Cognitive models for understanding and assessing spatial abilities. Intelligence: Reconceptualizaton & Measurement. Hillsdale, New Jersey: Lawrence Erlbaum Assoc.

Piaget, J. & Inhelder, B. (1948). The Child's Conception of Space. New York: W. W. Norton & Company.

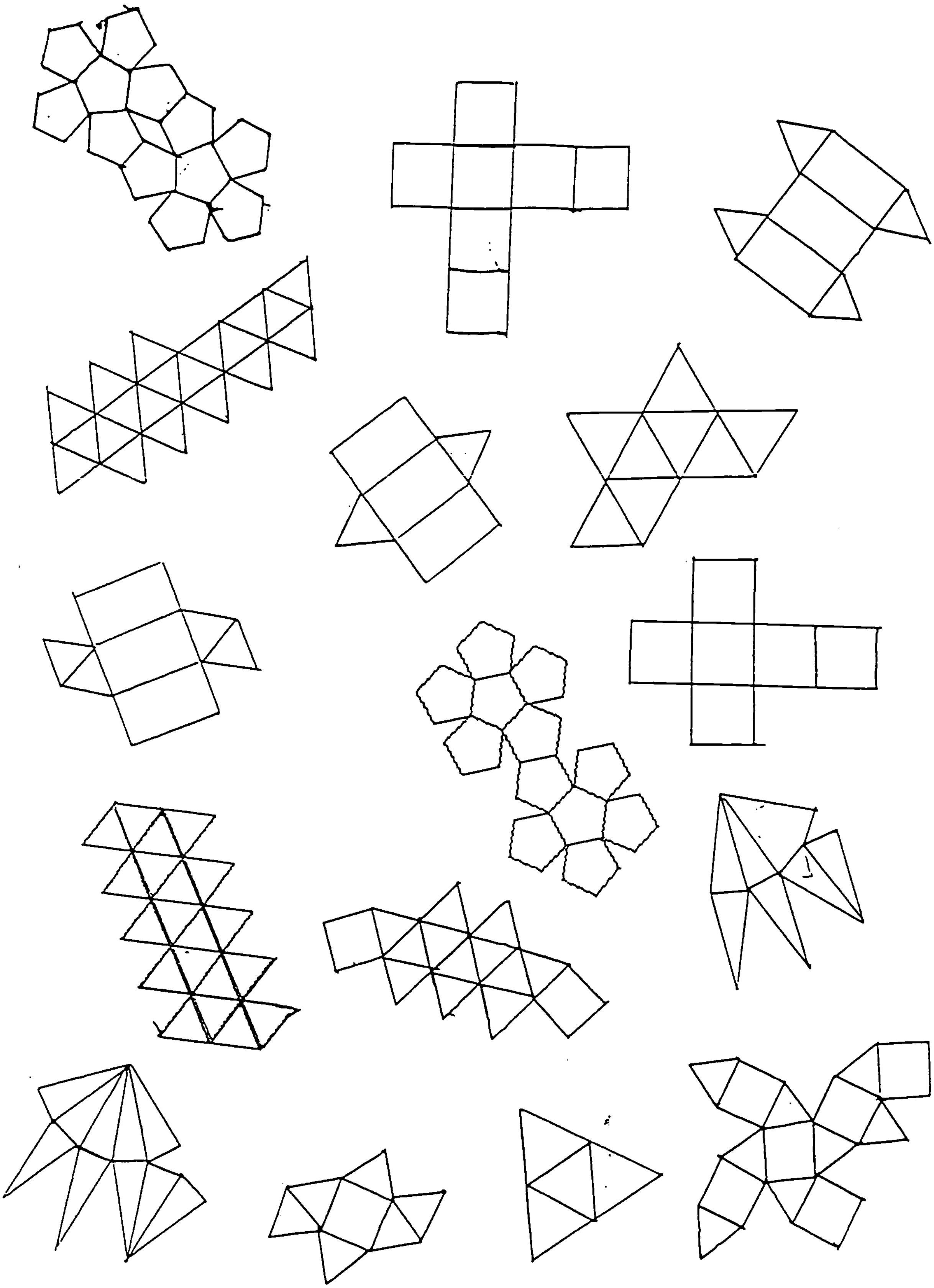
Piaget, J. & Inhelder, B. (1956). The Child's Conception of Space, Routledge and Kegan Paul, London, 1956.

Potari, D. & Spiliotopoulou, V. (1992). Children's representation of the development of solids. For the Learning of Mathematics, 12(1), 38-46

Pribyl, J., & Bodner, G. (1987). Spatial ability and its role in organic chemistry: A study of four organic courses. Journal of Research in Science Teaching, 24(3),229-240.

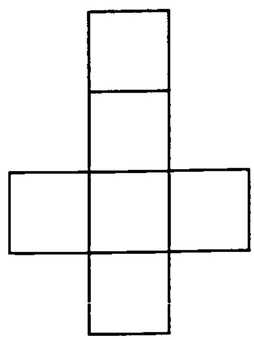
Vicente, K. J., Hayes, B. C., & Williges, R. C. (1987). Assaying and isolating individual differences in searching a hierarchical file system. Human Factors, 29, 349-359

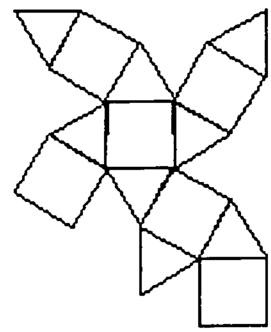
Appendix A



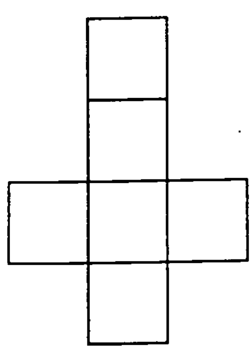
Appendix B

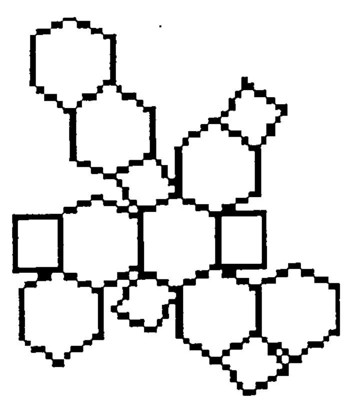
Nets given in the pretest





Nets given in the posttest





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