Relationship Between Earth-Science Education and Spatial Visualization

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ABSTRACT

The purpose of this study was to look for interrelations between the study of introductory geology courses and the development of spatial-visualization ability. The study was conducted among 32 undergraduate students during their first year of earth sciences study in the Hebrew University of Jerusalem. The students' spatial-visualization ability was measured at the beginning and at the end of the course by two different validated instruments. Pre- and post-geology scores were analyzed for any significant change and for correlation with final scores in the course. Results indicated that the students' spatial-visualization ability significantly improved after the first geology course was taken. Interviews revealed that the students claimed that only the earth-science courses required spatial-visualization skills. It is suggested that there is a two-way relationship between studying earth science and spatial-visualization skills. It seems that studying earth science itself might improve student spacial-visualization aptitude. The findings also support the notion that males develop better spatial-visualization skills.

Keywords: Education – geoscience; geology – teaching and curriculum; structural geology.

Much research has been dedicated to analyzing and understanding human spatial-visualization ability. Many of the articles published on this subject are concerned with the relationship between spatial-visualization ability and success in science and mathematics (Dyche and others, 1993). Besides its importance to these fields, spatial-visualization skills are vital to a wide variety of professions, such as engineering and architecture. Yet, despite the importance of this skill, large segments of the general populace do not perform well when confronted with spatial-visualization tasks (Bishop, 1980).

Unfortunately, there have been few consistent results with training methods that attempt to enhance spatial-visualization ability. For example, Smith and Schroeder (1981), Lord (1985), Lord (1987), Ben-Chaim and others (1988), Baenninger and Newcombe (1989), and Kiser (1990) all showed improvement with the training methods they introduced to students. However, studies by Mendicino (1958), Mitchelmore (1980), and Mundy (1987) found no such improvements.

Another aspect of research that has contributed to our knowledge of spatial-visualization abilities is based on the investigation of individual and group differences. It was found that there is a gender difference favoring males in the performance of different spatial-visualization tests (Maccoby and Jacklin, 1974; McGee, 1979; Kali and Orion, 1996).

One field of study that seems to show promise for improving spatial-visualization ability is earth science. In their daily working lives, geologists constantly deal with two-dimensional representations (such as maps, diagrams, or computer displays) of the three-dimensional world. Bezzi (1991) has developed a tool for improving the general spatial-visualization ability of students in order to improve their spatial-visualization ability in earth science. This study, however, was conducted to determine the relationship between learning earth science and the improvement of general spatial-visualization abilities.

Specifically, the following questions were addressed:

1) Is there a relation between spatial-visualization ability and learning achievement in geology?
2) Were students' spatial-visualization abilities improved following exposure to an introductory course in geology?
3) Was there a gender difference among the students studied?

Methods

The sample consisted of 32 first-year geology undergraduates who participated (and completed) a one-year introductory course in the Hebrew University of Jerusalem. The sample included only students who had completed spatial-visualization tests both at the beginning and end of the course, 71 percent of the students surveyed. The sample was broken down into 18 males (56 percent) and 14 females (44 percent).

During their first year most students studied a program that consisted of two parts: 1) introductory courses in earth sciences, including a two-semester course in geology, and one-semester courses in geomorphology, atmospheric science, and oceanography and 2) introductory courses in mathematics and sciences, including algebra, inorganic chemistry, and physics.

The data were collected with structured interviews and two (previously) validated spatial-visualization-aptitude tests. The interviews were conducted with six students at the end of the year. Their purpose was to explore the students' point of view about the relationships between their studies and their spatial-visualization abilities.

The aptitude tests were administered both at the beginning and end of the first year of studies. The tests utilized in this study were: the MGMP Spatial Visualization Test (Ben-Chaim and others, 1985) and

	MGMP – Pre		MGMP – Post		DAT – Pre		DAT – Post	
	r	P	r	P	r	P	r	P
Geology score	0.52	0.002	0.51	0.003	0.41	0.02	0.35	0.05

Table 1. Pearson correlation coefficients of the students' spatial-visualization test and their final geology score (N=32).

	Pre		Post			
Test	Mean	sd	Mean	sd	t	P
MGMP	60.9	18.1	71.1	18.9	4.2	0.0002
DAT	58.4	17.7	69.3	18.5	3.5	0.001

Table 2. Pre/post comparison of the study population (N=32) concerning the two spatial-visualization aptitude tests.

the Spatial Aptitude Test of the Differential Aptitude Tests (DAT) of The American Psychological Corporation.

Results

A (Pearson's) correlation test was conducted to determine the relationship between the students' spatial-visualization abilities and their final score in geology. High and significant correlation coefficients were found between each of the pre and the post spatial-visualization tests and the geology final score (Table 1).

Table 2 indicates that, following the first year of earth science, a significant improvement in spatial-visualization ability took place.

No significant gender differences in spatial-visualization abilities were found by a t-test analysis in relation to the DAT instrument, both pre and post tests, and the MGMP pre test. Nonetheless, a significant difference was found in relation to the MGMP post test where males' scores were found to be significantly higher than females' scores (P=0.005).

Table 3 shows that both sexes improved significantly in relation to the DAT, whereas only the males improved significantly with respect to the MGMP VSP test.

Interviews

Three males and three females were interviewed. Only one female claimed to have difficulty with tasks involving spatial visualization. However, the pre and post scores of each of the six indicated that a meaningful improvement in their spatial-visualization abilities occurred.

In addition, the members of this group were in agreement about the following aspects:

1) They identified specific topics from their earth science courses which required spatial-visualization ability. Particular emphasis was placed on this skill in their introductory geology course and their field work experiences.
2) In contrast, they could not identify topics in the other science courses they had completed which required spatial visualization.

		Pre		Post			
	N	Mean	sd	Mean	sd	t	P
MGMP VSP							
Male	18	63.0	14.1	79.0	10.7	5.4	0.0001
Female	14	58.3	22.5	60.8	22.4	0.8	N.S.
DAT							
Male	18	63.0	18.3	73.4	19.3	2.1	0.05
Female	14	52.4	15.5	63.9	16.6	3.7	0.003

Table 3. Pre/post comparison of the two spatial-visualization tests in relation to gender.

Based on the interviews, the topics in geology requiring spatial visualization could be classified into two basic groups:

a) Topics that could be learned through a concrete hands-on activity, such as field or laboratory problems on geological structures, igneous bodies, crystal structures, geological maps, or cross sections.
b) Topics that are related to more abstract processes, such as air-mass circulation in the atmosphere, water-mass circulation in the oceans, or the plate-tectonic model which students learned without any means of concretization.

Discussion and Conclusions

The high correlation coefficients between the students' spatial visualization and their achievements confirm Chadwick's (1977) hypothesis about the importance of spatial-visualization aptitude for learning and understanding earth science. The interviews corroborate this finding and further show that this cognitive aptitude can be divided into two main domains: topics involving concrete objects and topics involving configurations that are more abstract and are therefore more difficult to present in a 3-D model.

The effect found in this study supports the findings in other studies that suggested spatial-visualization skills can be improved by training. However, there is an important difference between those studies and this study. The improvement of students' spatial-visualization skills was usually reported in relation to studies aimed at evaluating specific training programs to improve spatial visualization (for example, see Kiser, 1990; Ben Chaim and others, 1988; Russell-Gebbet, 1985). The most important result of the current investigation was that the spatial-visualization abilities of first-year geology students were significantly improved regardless of any specific training program in spatial visualization.

The main question raised by this point has to do with the source of the improvement. The possibility of a retesting effect, meaning that repeating the spatial-visualization aptitude tests might have influenced this improvement, was already eliminated by Ben-Chaim and others (1988) who administrated the MGMP Spatial Visualization Test twice three weeks apart without any intervention to the same population and found no evidence that students had gained in performance from practice on the test. In the current study, the tests were given seven months apart, so it might be concluded that the retesting effect was negligible. Thus, the source of the improvement would only come from the first-year studies themselves. As was noted, the first-year program included introductory courses in earth sciences, chemistry, physics, and mathematics. However, only the earth-science courses emphasized topics that required spatial-visualization aptitude. This notion was strongly supported by the students' interviews.

It might also be noted that, with the exception of earth science, the students had already been exposed to courses in all of the basic sciences. Thus, if the study of the other scientific disciplines has an influence on spatial-visualization ability, it should already have had an effect earlier in high school. Consequently, it is suggested that the improvement of the students' spatial-visualization skills was mainly related to their exposure to the introductory earth-sciences courses.

Unfortunately, earth science has usually received less emphasis than the other basic sciences in the school curriculum. However, this study indicates that earth science may influence students' abilities in other sciences, such as physics or mathematics, where spatial-visualization abilities are important. Thus, students in their formative years would likely benefit from greater exposure to the earth sciences.

The fact that there were no statistical differences between the sexes, prior to the course agrees with both Armstrong (1980) and Fennema and Sherman's (1978) research that concluded there are no sex-related differences in spatial visualization. On the other hand, this finding is in conflict with many other studies that did find such differences (for example, see Maccoby and Jacklin, 1974; Harris, 1981; Liben, 1981).

Whereas both sexes improved in relation to the DAT, only the males' spatial-visualization abilities improved in relation to the MGMP SVT. This contradiction can be explained by Linn and Peterson's (1985) study that concluded "the magnitude of the (sex) difference depends on the test used" (p. 1488). Their additional conclusion that males perform at higher levels than females in mental rotation may explain the conflicting finding of the two tests, since many tasks on the MGMP SVT require mental rotation ability. The compilation of the two sources indicates that both sexes made substantial gain, but they still responded differentially to the program. This conclusion differs from the findings of Maccoby and Jacklin (1974), who concluded that: "it has not been demonstrated that male and female subjects respond differentially to training (in spatial tasks)" (p. 128).

Furthermore, the last two conclusions disagree with Ben-Chaim and others, (1988) who used the same MGMP SVT and found totally opposite results: a) sex differences in spatial-visualization abilities favored the males before the instruction and b) both sexes gained significantly from a training program in spatial-visualization tasks and responded equally to the program. It might be suggested that the females in this study are not a representative sample in that usually females with better than average spatial-visualization abilities choose to study geology.

The second conflict may indicate that some element of the course itself provides an advantage to the males in the development of spatial-visualization skills. No direct evidence was found in this study for the gender difference; however, a potential source of this phenomenon might be the field camp. In general, Israeli males are more familiar with the field environment because of their military background. This familiarity breeds a certain level of dominance in the field camp. Consequently, males may acquire a higher level of spatial-visualization skills during their field work. Conversations with some of the course's staff confirmed the males' "dominance." However, more investigation is needed to test this hypothesis.

Summary

This study supports the idea that spatial-visualization ability is strongly related to earth-science studies and can be improved even without a specific training program. It is suggested that completing a one-year program in earth sciences significantly contributes to the improvement of an individual's spatial-visualization abilities.

This study also supports, in principle, the existence of a gender difference that favors males in relation to spatial-visualization skills, particularly with respect to the gain acquired through educational intervention.

It is clear that the sample size of this study does not allow us to generalize about the present findings. However, the important findings of this study in relation to earth-science education suggest that more research is needed in this area. The authors therefore invite other researchers to collaborate and to expand this study to other settings.

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Food for Thought

The attraction of the scientific method goes beyond its enormous power and scope .... There is also its uncompromising honesty. Every new discovery, every theory is required to pass rigorous tests of approval by the scientific community before it is accepted. Of course, in practice, scientists do not always follow the textbook strategies. Sometimes the data are muddled and ambiguous. Sometimes influential scientists sustain dubious theories long after they have been discredited. Occasionally scientists cheat. But these are aberrations. Generally, science leads us in the direction of reliable knowledge.

Paul Davies, 1992, *The mind of God – The scientific basis for a rational world*: New York, 254 p. (from p. 14).