DOCUMENT RESUME

ED 459 414 CG 031 471

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TITLE	Why Do Chinese Students Perform Well on Spatial Tasks? Chinese Teachers' Perspectives.
PUB DATE	2001-08-00
NOTE	21p.; Paper presented at the Annual Conference of the American Psychological Association (109th, San Francisco, CA, August 24-28, 2001). Funded by Marion and Jasper Whiting Foundation.
PUB TYPE	Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	Academic Ability; *Chinese; *Cognitive Processes; College Students; Elementary School Students; Elementary Secondary Education; Environmental Influences; Foreign Countries; Higher Education; Perception; Secondary School Students; *Spatial Ability; Teachers; *Thinking Skills
IDENTIFIERS	China (Beijing)

ABSTRACT

This study assessed Chinese teachers' perspectives on why Chinese students perform well on spatial tasks. The study interviewed 17 male and 12 female teachers of Chinese language, math, science, and 6 other subjects, from elementary schools, high schools, and colleges of Beijing, China. The responses indicated that the Chinese teachers perceived that multiple environmental factors contributed to the Chinese students' spatial ability. These factors were Chinese culture, written language, life experience, and several school-related factors; including the academic subjects taken by the students. Some of the responses appear contrary to the research findings in the United States, whereas other hypotheses suggest avenues for future research. (Contains 22 references.) (Author/JDM)

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ED 459 414

Paper presented at 2001 Convention of American Psychological Association

Why Do Chinese Students Perform Well on Spatial Tasks? Chinese Teachers' Perspectives

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Note: Heart-felt thanks to all the participants from Beijing, P. R. China, to Marion and Jasper Whiting Foundation for funding, and to Dr. Louis Kruger for his thorough review of this paper.

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Abstract

This study assessed the Chinese teachers' perspectives on why Chinese students perform well on spatial tasks. The author interviewed 17 male and 12 female teachers of Chinese language, math, science and 6 other subjects, from elementary schools, high schools and colleges of Beijing, China. The responses indicated that the Chinese teachers perceived that multiple environmental factors contributed to the Chinese students' spatial ability. These factors were Chinese culture, written language, life experience, and several school-related factors, including the academic subjects taken by the students. Some of the responses appear contrary to the research findings in the United States, whereas other hypotheses suggest avenues for future research.

Why Do Chinese Students Perform Well on Spatial Tasks? Chinese Teachers' Perspectives

One of the puzzles for American educators is: Why do Chinese students perform better than United-States students on mathematics and spatial tests despite poorer living conditions and schools resources? A review of literature did not yield any systematic cross-cultural studies that answer this question. The purpose of the present study was to obtain Chinese teachers' perspectives on the causes of this apparent gap in performance.

Recent research has confirmed that the Chinese students do indeed perform better on spatial (Li, Nuttall & Zhao, 1999a; Li, Nuttall & Zhao, 1996) and mathematical tasks (Stevenson, Chen, & Lee,1993; Stevenson, Lee, Chen, Lummis, et al., 1990). One study (Li, Nuttall & Zhao, 1996), for example, confirmed that the Chinese students significantly outperformed their American peers on the Piagetian (Piaget & Inhelder, 1948/1956) Water Level Task (WLT). The WLT is a well-studied spatial task. It requires correct anticipation of water surface orientation in tilted bottles that are half-filled. According to Piaget, success on WLT reflects the person's spatial competence, that is, the ability to use a Euclidean system of reference to organize spatial experience. Li, Nuttall & Zhao (1996) replicated a WLT test conducted by Sholl and Liben (1995) and found that performance of 297 Beijing, Chinese undergraduates' on the WLT was considerably superior to that of American undergraduates tested by Sholl and Liben. About 91% of the Chinese males and 76% of the Chinese females were successful on the WLT (Li, Nuttall & Zhao,1996) compared to 56% of the American males and 26% of the American females found by Sholl and Liben (1995). Li, Nuttall & Zhao (1999a) found in a later study that Chinese in China outperformed Chinese-American college students on the WLT. In addition, among Chinese-American males, those who could write Chinese performed significantly better than those who could not.

An examination of the results of subgroups (Li, Nuttall & Zhao,1999b) suggests that either cultural or educational factors might explain differences in performance on the spatial test (WLT). In particular, a higher percentage of 8th grade boys from a prestigious school in China were successful in mastering the WLT than a similar group of Chinese boys from non-prestigious school. (However, it should be noted that this difference might also be the result of pre-existing differences in ability).

Another possible explanation of the performance differences is the difference between the Chinese and English language. The process of writing Chinese characters might provide more experience with two-dimensional spatial relations in the Euclidean system than the process of writing English (Li et al., 1999a) For example, the words sky (天), earth (地), she (她), and outstanding (杰), clearly require attention to both a vertical as well as a horizontal dimension. The worksheet frame for beginning writers of English provides horizontal lines but no obvious Euclidean system with both horizontal and vertical coordinates as does the worksheet frame for writing Chinese characters. According to Piaget and Inhelder (1948/1956), the awareness and the ability to use a frame of reference is crucial to the solution of the WLT. From this Piagetian perspective, the process of writing Chinese may help develop the awareness of the need for external anchors and the ability to use them. The writer of Chinese is accustomed to referring to the square frame as the environment of focus, and the table line in the WLT resembles this external reference. (See Figure 1).

A third possible explanation concerns curricular differences between the United States and China. The Chinese students in China have longer (5 hours/ week in the seventh grade) and more focused work on geometry during the six full years of high school mathematics training (Department of Education of the Peoples Republic of China, 1992) as contrasted to the one half to one year of focused geometry work in the United States. In the 31st International Mathematics Olympics, the Chinese students attained the highest scores. More specifically, they had a perfect score on the geometry part (Zhang & Kuo, 1990). Because the Euclidean spatial system is formally taught in geometry, the extensive training in geometry may well-prepare the Chinese students for spatial tasks such as the WLT.

Although our studies have found a relationship between language and geometry in regard to spatial reasoning, there are some unanswered questions. First, what cultural and educational factors might nurture spatial ability? Second, how might Chinese schools facilitate children's spatial skill development through curricula and teaching? To begin to answer these questions, we need to include Chinese teachers' perspectives, because Chinese teachers may have more direct observations of how Chinese culture and education relate to students' spatial performance. Although their perceptions will not provide definitive answers to these questions, their opinions might provide useful hypotheses for further research. Unfortunately, the Chinese teachers' perspectives on this issue are not reflected in the available English or Chinese literature. The current study assessed Chinese teachers' and educators' perspectives on why Chinese students perform well on spatial tasks.

Method

Participants

All 29 participants, 17 males and 12 females, were teachers from China. Nine were from elementary schools, 14 were from high schools, and 6 were from colleges in Beijing. They were selected from both prestigious and non-prestigious schools. Prestigious schools typically require a higher entrance exam score than other schools. The participants were teachers of math (n=6), Chinese language (n=7), physics (n=3), biology (n=3), nature (a science course at elementary school level; n=2), psychology (n=2), education (n=1), art(n=3), gym (n=1) and financing (n=1). The average age was 51, ranging from 22 to 77. To obtain a wide range of views, teachers of all seniority levels were included, including consultants for textbooks of mathematics, Chinese, and physics. The average years of teaching experience were 18, ranging from 1 to 45. Eight of the participants have visited the United States. Among the eight, three have observed children studying in American suburban schools, and four have visited educational systems in other countries such as Japan, France and Germany.

Materials

Interview questions. The following four interview questions were developed by the researcher for this study.

1. In China, what life experience might facilitate the development of spatial ability to solve the Water Level Task?

2. What aspects of education in China might facilitate students' spatial ability?

3. Specifically, what content from what curricula might facilitate the development of spatial ability? Please explain and give examples.

4. What teaching process, methods, equipment or environment might facilitate the development of spatial ability?

Procedures

The interviews were conducted individually in Chinese by the researcher who is fluent in Chinese and English. The interview locations were arranged for the participants' convenience, either in participants' offices or home or the researcher's room. The interviewees were allowed to talk as long as they wanted in response to a question. The average length of the interview was 45 minutes, ranging from 15 minutes to 2 hours and 55 minutes. The 29 interviews were completed in August of 1998, in Beijing. The responses were recorded by the researcher.

When a interviewee asked what the WLT was, the researcher showed him/her a sample WLT (see Figure 1). To avoid influencing the interviewee's responses, the author did not share her own views or research findings regarding what factors are related to performance on the WLT or other spatial tasks.

After the interview, the researcher reviewed the responses to each research question and developed several mutually exclusive themes that reflected those responses (The themes are listed under each research question in Results section). Two research assistants independently matched each response to its corresponding theme. Each answer was classified only once, and to only one theme. The inter-rater agreement was 97.5%.

Results

The following is a summary of the interviewees' answers to each of the research questions. It is reported according to the sequence the questions were asked. Under each question, the answers are organized according to their themes. If respondents provided explanations of a theme, they are cited under that theme. The number of respondents who share the same view is reflected in the (n=).

Q1. In China, what life experience might facilitate the development of the spatial ability to solve the Water Level Task?

1. Experiences with water may help students understand the concept of liquid horizontatility (n=11).

The interviewees gave the following examples of how life experience with water might facilitate the WLT: "In daily life (eating, drinking, playing, housework), Chinese children have extensive experience with phenomena like the Water Level Task (WLT). For example, in China, most people cook for themselves and their bottles for vinegar and soybean sauce are all transparent. In addition, through housework such as washing dishes and vegetables, and through the experience of drinking water and soup by holding up the glass, cup or bowl, children see water surface in a tilted container everyday". "In some rural areas, fetching and carrying 2 buckets of water with a pole over the shoulder provides the experience of seeing water levels in a tilted container". "Many children in China also play with water because they don't have many toys". Thus, some interviewees believed that intelligent children in third grade or above would be able to develop an understanding of liquid horizontality from their experience.

2. Experience of writing Chinese characters might help brain development and imagery thinking(n=6).

"The experience of learning Chinese characters might facilitate imagery thinking through the process of associating the characters with sound and meaning (n=4). This is the result of the structure of the characters". Two teachers of Chinese language used the six types of character construction (Xu, 1979) to illustrate the point. "In Type One, a character indicates a thing. For example, the meanings of the words up (上) and down (下) are suggested by positions of the vertical lines and the dots above or below the horizontal lines. Type Two is pictorial. The characters look like the pictures of the things that they represent. For example, the original forms of the words sun (日) and moon (月) look like the pictures of the sun and the moon. Type Three involves the combination of form and sound. For example, the left part of word river (河) resembles flowing water, whereas the right part provides clues for pronunciation. Type Four uses analogy. For instance, the left part of the word letter (信) symbolizes a person and the right part is a word which means "speech". Thus, a person and a speech make the word "letter". Type Five is derivation, in which a new character is derived from an old one. For instance, the word test (考) was developed from the word old (老). Type Six uses a sound to indicate a meaning, for example, the words long (长) and command (令)".

"Because of these features of Chinese characters, individuals need to establish associations between the character and its pronunciation and meaning in order to learn the written language". Some teachers speculated that interacting with the comprehensive structures of the characters might involve more right brain activities than that with a phonetic language such as English. "The processes of learning and using the Chinese characters appear to involve coordinated activities of the whole brain"(n=2). Thus, "it may stimulate both hemispheres of the brain and cause better coordination of the two hemispheres" (n=2). "By the 5th grade, pupils learn 2,500 Chinese characters (see Chinese for Elementary Pupils by Chinese Language Textbook Program, 1983). With such a long term training, Chinese students might be better equipped for spatial tasks such as the WLT". Some teachers noted that bright Chinese children can use intuitive and holistic thinking skills, and get to the heart of the problem right away.

3. The experience of sharing a small living space with others may make Chinese children more perceptive of space, pay attention to details of a spatial setting and how to organize and use space efficiently (n=4).

4. Chinese are good at both logical and imagery thinking (n=3).

Some teachers believed that traditional Chinese culture emphasized philosophy, imagination, and analyses of relations among things. The Chinese have become good in relational and imagery thinking, which is different from the thinking style of Westerners.

5. Using chopsticks since early childhood requires improved fine motor coordination of the fingers (n=2). A couple of teachers speculated that this process may stimulate the brain cells.

6. Early childhood education provides children extensive pre-academic skills (n=2).

Two teachers who are also parents explained: "China has a national policy of only one child per couple. Therefore, parents and grandparents are extremely invested in the well-being of this only child. As it is very competitive to gain acceptance into colleges, parents feel pressured that they have to start preparing their children for the competition at an early age. For example, parents teach toddlers colors, numbers, shapes, rhymes and names wherever they go, including bus-stops, stores and trains. It is commonplace to see a Chinese preschooler recite dozens of poems, count to a hundred, name a dozen colors, shapes, and make a complex block-building".

7. Influenced by Confucius, the Chinese students traditionally approach problems in an attentive, observant, and thorough way. Their hardworking and earnest attitudes help them succeed (n=2).

8. Chinese have been good at math for hundreds of years and one needs to use mathematical concepts to do well on WLT (n=1).

9. Chinese people are gifted in spatial relations (n=1).

Q2. What aspects of education in China might facilitate students' spatial ability?

1. School experience helps students develop math, science and test-taking skills that may contribute to better performance on the WLT. (n=6).

"Chinese schools provide a solid foundation of knowledge, especially in math and science. Students have homework everyday in these subjects". The teachers who have visited American schools commented that Chinese textbooks cover the math and science more extensively and intensively than American textbooks. "In China, systematic, formal, and high standards are held in math and all science courses. Schools emphasize competency and skills. The teachers in China give specific directions in classes and are strict with the students regarding the academic standards". "Chinese students experience many paper-pencil tests. Thus, they seem proficient at taking paper-pencil tests". In addition, "the expectations of academic success for males and females are similar. This motivates females to develop science skills"(n=1).

2. Intensive and extensive geometry, math and science training provides the knowledge base for solving the WLT (n=6).

"Classes in geometry and physics emphasize logical thinking and reasoning extensively. Earlier math training may include the knowledge needed for WLT, such as a

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reference system with coordinated horizontal and vertical system. For instance, in elementary school, 'starting geometry' teaches the coordination of vertical and horizontal axis". A geography teacher reported that the geography textbook for the 6th grade also covers longitude and latitude.

3. Chinese schools train students how to think, observe and imagine through subject courses (n=23). The overall education in China facilitates students thinking (n= 1).

Teachers of different subjects elaborated how each subject enhances thinking skills:

#1 Chinese language classes facilitate students' thinking (n=7).

"Learning the Chinese characters may make the children pay attention to details. When teaching the characters, teachers emphasize developing reasoning, imagination and association. Multiple abilities are also developed through the task of systematically describing a picture, a common task in Chinese language classes in elementary schools. In Chinese language classes, students are trained to think critically and synthesize ideas through text analysis. These abilities include observation, imagination, understanding a situation, and express oneself logically. These abilities may help one solve the WLT".

#2 Math classes facilitate students' thinking (n=6).

"Generally, in China, teachers teach students how to think, how to approach a problem in math class and emphasize understanding and using the concepts flexibly. Systematic, extensive and rigorous training of math throughout grades 1-12 leads to good reasoning skills and logical thinking". "To facilitate problem solving, Chinese math teachers instruct students to find the essence and the unchanged elements of an entity. The thinking skills developed in math class might generalize to problems such as the WLT. For example, in the WLT, the table line is stationary, and thus might be considered an unchanging element of the problem".

#3 Physics/Science classes facilitate students' thinking (n=3).

"From first through sixth grade, Chinese students have 45 minutes a week of science activities. In Science Activity classes, teachers emphasize process and operation,

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through which students develop abilities to observe and reason, to synthesize and analyze". "In physics, teachers integrate logical and imagery thinking skills".

#4 Art classes train observational skills and imagination (n=3).

"Chinese paintings emphasize philosophy and reasoning. For example, to draw a farmer's hand, you base your understanding of farmers but not on observing one farmer's hand. Art is taught from first through ninth grade, 45 minutes/week. Both Chinese and Western art are taught. Instruction of art can facilitate an ability to systematically observe and imagine an object or complex entity. The training in observational skills might help with the WLT".

#5 Physical Education(n=1).

"In gym class, when children learn to balance, they have to observe the model and then retain the images they have observed in their mind, and then turn these images into physical postures. This process may stimulate imagery thinking. Sports and performing art may involve similar observation and imagination processes to visual art".

4. Students have seen liquid in different positions in tubes in chemistry and physics (n=2).

"The course NATURE taught in the 5th grade includes the knowledge of water horizontality". "The physics curriculum addresses the content of horizontality". "Chemistry experiments provide numerous opportunities for students to see and measure liquid in tilted tubes".

5. Generally, the concept of horizontality has been developed through secondary education science classes (n=1).

6. Influenced by ancient dialectic thinking style, teachers teach students to see things dialectically; that is, to see both sides of things, various perspectives of things, and the relationships among things. Dialectic thinking style might help one understand a problem more comprehensively (n=1).

7. Chinese students use calculators less than their American counterparts. This might direct students to use their problem solving skills when tackling tasks (n=1).

8. The textbooks of Chinese language contain simple science facts that might help with the WLT (n=1).

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9. Extra curricular activity helps students gain more experience with science which might facilitate the WLT (n=1).

A science teacher reported that, to stimulate interest in science, he and his colleagues encouraged pupils to read all kinds of science journals for children. One third of children in his school (an average elementary school in Beijing) subscribed to a journal and joined after-school science-interest groups. In the science-interest groups, students learned more about science, solved more science problems, and conducted more science projects.

Q3. Specifically, what contents from what subjects might facilitate the development of spatial ability? Please explain and give examples.

1. The Chinese curricula for grades 1-12 contain more difficult math and science contents than most of the countries in the world (n=1).

2. Geometry teaches the coordination of the vertical and horizontal axes (n=6).

3. In Nature class, 5th grade students see water in tilted tubes at an 45 degree for an experiment of steam, which reveals that water surface stays horizontal regardless of the position of the tube (n=1).

Q4. What teaching process, method, equipment or environment might facilitate the development of spatial ability?

1. Good integration of theory and practice in math class might help students develop a better understanding of the geometric concepts. For example, when learning how to compute the surface area of circles and triangles, students make these shapes.

2. Considerable practice led to better grasp of the skills.

"In Chinese class, 1st and 2nd grade pupils learn between 600 and 700 words, which enable them to write notes".

3. Students are trained to be observant and to learn fast. The observational skills and learning skills might facilitate students solving new problems, including spatial problems such as the WLT.

Discussion

The teachers' or professors' answers to the questions were based on their own observations of the Chinese culture and education. These responses provided several hypotheses regarding why Chinese students perform well on spatial tasks. Some of the hypotheses are based on specific information (e.g., textbooks, readings of Chinese history, culture and language), some are based on direct but informal observations of daily life (e.g., experience with water, small living space) or school practice (e.g., rigorous training in math and science, high standard of academic performance). Some are personal views (e.g., Chinese are gifted in spatial tasks). This discussion focuses on the hypotheses that were most frequently mentioned by the respondents.

In China, what life experience might facilitate the development of spatial ability to solve the Water Level Task?

Many Chinese teachers believed that a typical Chinese student's life experience of seeing water in tilted containers facilitates the WLT. However, American scholars (Hecht & Proffitt, 1995) found that WLT performance declines with the experience of seeing liquid in tilted containers. When other conditions were similar, bartenders from Munich made more errors on the WLT than bus drivers. Practical experience, according to Hecht and Proffitt (1995), promotes a functionally relative perspective, in which the orientation of liquid's surface is evaluated relative to that container as opposed to the environment- relative reference that facilitates the understanding of the WLT. Furthermore, explanation and demonstration of water horizontality was ineffective in improving children's performance on WLT (Smedslund, 1963). Even if there was improvement after training, there was no apparent transfer (Beilin, Kagan, & Robinowitz, 1966) or generalization (Robertson & Youniss, 1969) to similar tasks. Similar ineffectiveness was found in the demonstration of water horizontality for improving WLT performance among college women (Thomas, Jamison, & Humel, 1973; Liben ,1978).

Nevertheless, can we infer that the experience with water does not help the Chinese with the WLT because it does not help the people from Munich? There is a possibility that the Chinese writers benefit from observing water in tilted containers for solving the WLT while non-Chinese-writers do not. Chinese writers may be more used to applying the environment-relative reference because of their extensive practice of writing

Chinese characters in a Euclidean-like system (Li, et al, 1999a). Individuals who have developed a habit of using the Euclidean system may respond to the experience with water differently than those who have not developed such a habit. A comparative study between Chinese-writing and non-Chinese-writing bartenders may help answer this question.

Educators in China also thought of the Chinese written language's impact on spatial ability. However, the possible impact they discussed are different from Li Nuttall and Zhao's (1999a) hypothesis that writing Chinese provides experience with the Euclidean system. Some Chinese teachers believed that learning and using the Chinese characters stimulate both sides of the brains and strengthen their connections. Others believed that learning Chinese characters facilitates imagery thinking. If this is true, then learning Chinese characters may facilitate performance on the WLT, because mental imagery is one of the component skills of the WLT (Kalichman, 1988). Some scientists explored the relationship between reading Chinese characters and brain activities through examining the evoked potentials by the characters (Shimoyama, Nakajima, Ito & Shibata, 1997). However, no study has tested whether learning Chinese characters arouses more brain activity or more neuron development than learning English. In addition, no study has tested whether using Chinese characters leads to more imagery thinking than using English.

The hypotheses of language-brain development connection may lead us to look at the development of spatial ability from a broader perspective. That is, to study how a written language may affect brain development that might, in turn, affect spatial ability development.

Three other possible cultural origins of Chinese students' superior spatial performance pointed out by the Chinese teachers also sound logical but have not been investigated: First, the experience of sharing a relatively small physical space with others may make the Chinese people more perceptive of space. Second, using chopsticks from a very young age might provide more stimulation to the brain cells. Third, one child per couple policy leads to early education, and the latter might provide children extensive pre-academic skills, including spatial skills.

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What aspects of education in China might facilitate students' spatial ability?

The rigorous training of math and science in China that was mentioned by the interviewees also has been noted by people who have observed the United States and Chinese school systems. For example, in mathematics class , in the Fall semester, a second grade of an American suburban school system (whose college entrance rate was over 95%) was teaching simple addition and subtraction, e.g., 2+47=? 100+0=? 9-6=? 11-4=? Meanwhile, a second grade of an average school a city in China was reviewing more sophisticated addition and subtraction, e.g., 54+26+15=? 90-58-24=? and teaching times and division, e.g., 5x3+20=? 63/9=? (Book 3, Mathematics for Elementary Pupils by Li & Zhang, 1994). Another example is shown through a student's experience. An average 9th grade student from an American suburban high school (whose college entrance rate was over 90%) had to go to the 8th grade when transferred to an average high school in Beijing, China. This placement was based on his skill level of mathematics, physics, chemistry and biology as measured by the school entrance examinations for all students, including transfers. The student was fluent in Chinese and English. He worked much harder than he used to in the United States once he transferred to his new school. He was struggling to keep up with his peers in the 8th grade in China. This student was not alone. Other Chinese students who transferred from high schools in the United States to China have had similar experiences.

The Chinese teachers' hypothesis that the extensive math and science training enhances students' spatial ability is supported by Li, Nuttall and Zhao's study (1999a), in which, the Chinese undergraduates in Beijing (who were assumed to have both the language and the extensive math training) outperformed Chinese-American undergraduates in Boston.

The Chinese language teachers believed that their language classes might enhance thinking skills, such as verbal reasoning skills required for the WLT. Although the connection between verbal and math abilities is suggested by the high correlation (r = .60s) between SAT verbal score and SAT math score (Cohen, Swerdilik & Smith, 1992), there is no study indicating that Chinese language class provides more training of thinking skills than English language class.

Three major limitations of this study should be noted. One is the small sample of one city used in the study. Thus, it is not known if this sample is representative of Chinese educators in general. A second limitation is that this study investigated educators' perceptions. Direct measurement of the variables might either confirm or disconfirm these perceptions. A third limitation concerns possible interviewer bias. All the interviews were conducted by one researcher. This person's cultural and educational background, gender and profession might affect the interviewees' responses.

Conclusions

From the perspectives of the teachers from the nine disciplines, it seems that culture, life experience, multiple school factors, and multiple subjects (not only math and science but also language, art, and gym) might contribute to the development of spatial ability. Some life and educational experiences are directly related to the development of spatial concepts or perceptiveness of spatial relations. Some are indirectly related to superior spatial performance through strengthening general cognitive abilities such as skills of observation, imagination, analysis and synthesis. In this light, we may need to break the boundaries of different subjects/disciplines and consider the connections among different subjects, and different aspects of life, when studying or facilitating the development of spatial ability. An interdisciplinary approach may be more effective in science teaching.

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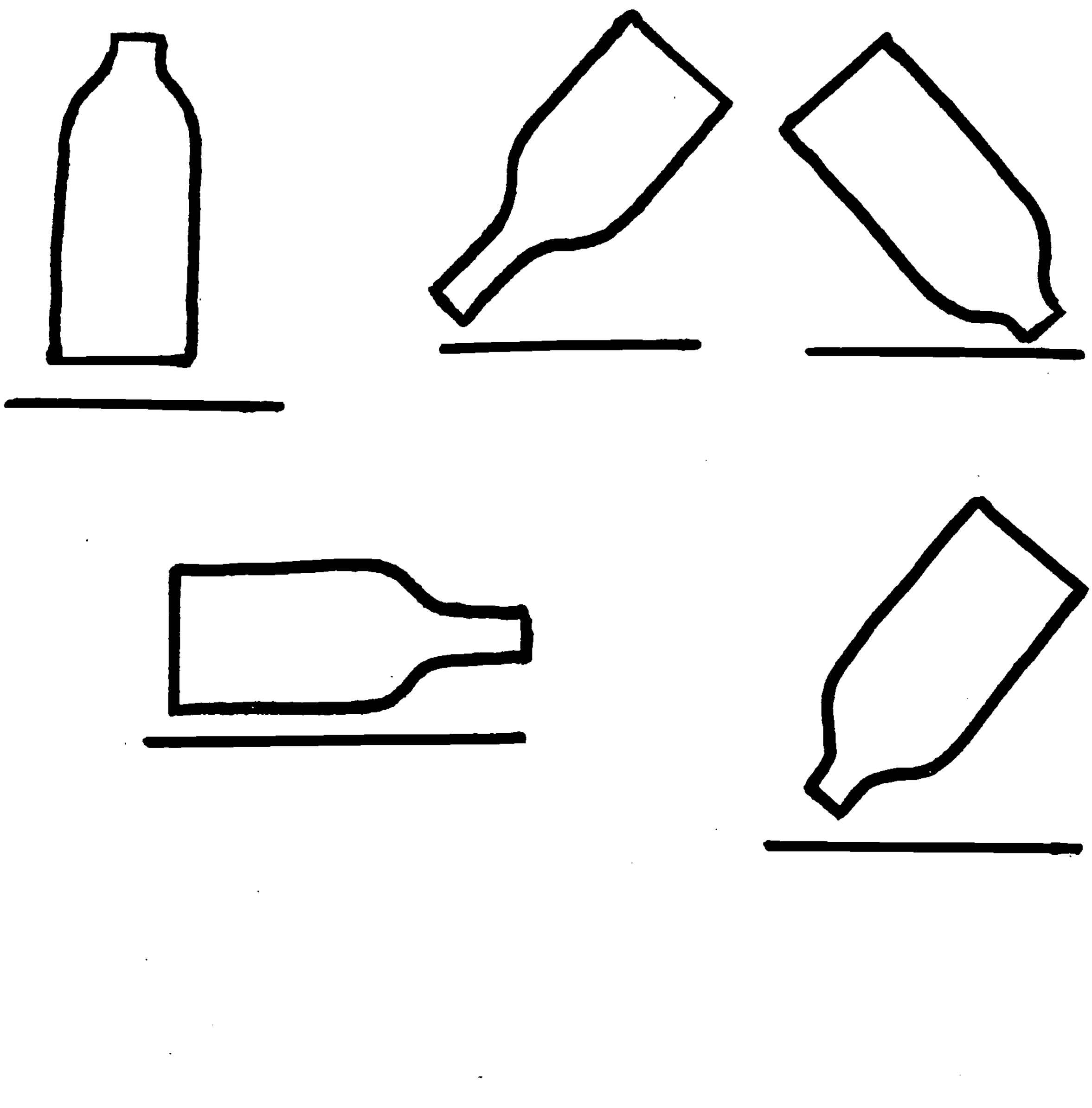
Figure 1

Sample Water Level Task



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Title: Why Do Chinese Students Perform Well on Spatial Tasks? Chinese Teachers' Perspectives

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Corporate Source: Dept. of Counseling and Applied Educational Psychology, Northeastern University

Publication Date: August, 2001 presented at APA Annual Convention

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