Gifted Students With Spatial Strengths and Sequential Weaknesses: *An Overlooked and Underidentified Population*

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Gifted students with spatial strengths are often overlooked and underserved in American schools. These students have remarkable areas of talent but often have verbal learning difficulties that prevent them from being identified for gifted services. This article focuses on definitions of spatial ability, characteristics of these learners, possible identification procedures, effective teaching strategies, and possible social development concerns of these students. The dwindling numbers of American students pursuing higher level degrees in mathematics and science, natural strength areas for students with spatial strengths, emphasizes the reasons educators need to identify and encourage these students at an early age.

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What might Albert Einstein, Auguste Rodin, Thomas Edison, Pablo Picasso and Leonardo daVinci have had in common? All made significant contributions to society but, although they were extraordinarily successful, biographical evidence suggests that each may have had substantial learning difficulties during their childhoods (Dixon, 1983; West, 1991). These individuals pursued work that required them to use their unique spatial strengths, but their learning difficulties revolved around sequential activities that were areas of weakness. Edison was considered "dull" by his teachers, Einstein did not speak until the age of 4, Rodin's work in school convinced his father that he was uneducable, daVinci is well known for his mirror writing, and Picasso had such difficulty with reading and writing that he spent his time in school drawing instead (Dixon). Their mediocre academic performances masked their superior spatial abilities. Had these creative individuals failed to find an avenue to follow and a venue in which their talents were valued, their gifts to society might have been lost. A better understanding of children who possess both outstanding spatial abilities and weak sequential skills will enable educators to more effectively teach these children in the classroom, perhaps ensuring that the next generation of Einsteins and daVincis will be more readily discovered.

What is Spatial Ability?

Spatial ability involves the visual manipulation of objects (Gardner, 1993), the ability to comprehend the relationships between fluid, changing patterns (Dixon, 1983) and the ability to manipulate complex visual material (Shea, Lubinski, & Benbow, 2001). Spatial ability is a dimension of cognition that combines with verbal and quantitative abilities to define how an individual perceives the world and acquires new knowledge (Gardner; Shea et al.). Researchers have proposed two methods of knowledge representation, the verbal code and the imagistic code (Gardner). Verbal coding refers to linguistics and individuals with talents and strengths in this area have the ability to express themselves easily with words (e.g., authors, playwrights, and poets). The imagistic code refers to the ability to create and manipulate images in the mind. Individuals who possess spatial strengths are adept at using images to search for solutions to problems and to express their thoughts. Thomas West (1991) describes a hierarchy in spatial thinking skills in which each step is more complex than the one before, as described in Figure 1. West views the process of spatial thinking to be manifested in the creative work of such persons as Picasso, Edison, Rodin, da Vinci, and Einstein.

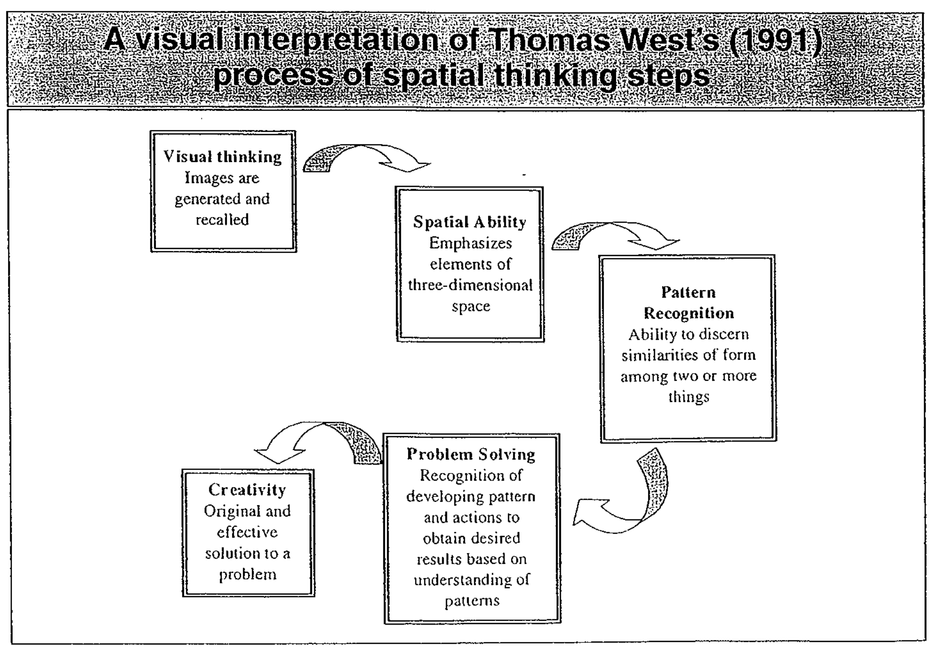

Figure 1

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To understand the differences between spatial and verbal intelligence, it is important to examine working memory (WM), which involves the temporary storage and manipulation of information, as it is necessary for a wide range of complex cognitive skills (Baddeley, 2003). "WM...may be the crucial underpinning (or at least an important component) of the well-known psychometric concept of general intelligence" (Miyake, Friedman, Rettinger, Shah, & Hegarty, 2001, p. 621). Neuroimaging studies of the brain have shown that accessing the imagistic code and the verbal code are distinct processes. Baddeley's theory of WM proposes three major components that comprise working memory: the phonological loop that manages verbal material, the visuospatial sketchpad responsible for processing visual-spatial material, and the central executive element that regulates the phonological loop and the visuospatial sketchpad. The central executive is responsible for attentional control and is a principal factor in determining individual differences in working memory span.

The percentage of American students pursuing careers in fields which utilize spatial skills such as mathematics and engineering is far below the percentage of students pursuing careers in verbally based domains such as business and the humanities.

Research suggests that phonological working memory and visuospatial working memory are separate entities and involve different neurological channels. Smith and Jonides (1997) used positron emission tomography (PET) to determine which areas of the brain are active when the different working memory systems are engaged. Their research found that when an individual was involved in solving a task using spatial memory, all four areas of the brain that were activated were located in the right hemisphere, whereas six of the seven areas activated while using verbal memory were in the left hemisphere, with the seventh being a midline structure. More recent research confirms and expands on the asymmetry between the phonological (verbal) and visual-spatial domains. Miyake et al. (2001) researched the roles of short-term memory (STM), responsible for simple storage tasks, and WM, which is more complex and involves not only storage but also processing of information. A partitioning of STM and WM was evident in the phonological loop with the two forms of memory being related but separable constructs.

> The nature of this separability is illuminated by the additional finding that the WM span tasks were able to predict performance on general fluid intelligence tests even after the common variance associated with the STM span tasks was partialed out, whereas the STM span tasks were no longer significantly related to general fluid intelligence after the common variance associated with the WM span tasks was partialed out. (Miyake et al., p. 622)

This separation indicates that the central executive functioning is more involved in WM tasks and the WM span tasks are better predictors on cognitive tasks than STM span tasks.

While the visuospatial domain has not been studied as extensively as the verbal domain, evidence suggests that the distinction between the STM and WM is not as pronounced in the visuospatial sketchpad as it is in the verbal domain (Miyake et al., 2001). The central executive is involved in both the simpler tasks used to test STM and the more complex tasks of the WM.

> This extensive executive involvement even for the simpler visuospatial STM span tasks is consistent with the proposal that the visuospatial sketchpad is closely tied to the central executive as well as with the suggestion that the maintenance of even a single item may require central executive involvement. (Miyake et al., p. 632)

The strength of the association between the visuospatial sketchpad and the central executive indicates that assessment of spatial tasks may be more closely related to general intelligence than to tests of verbal skills.

Why Foster Spatial Strengths?

The traditional American educational system is focused primarily on verbal skills, rarely emphasizing the development of spatial skills. College admission tests, traditionally used to determine entrance to undergraduate and graduate programs, such as the Scholastic Aptitude Test (SAT) and the Graduate Record Exam (GRE), do not assess spatial ability (Gohm, Humphreys, & Yao, 1998). The percentage of American students pursuing careers in fields which utilize spatial skills such as mathematics and engineering is far below the percentage of students pursuing careers in verbally based domains such as business and the humanities. Among undergraduates enrolled at universities and colleges in the United States who had declared a major during the 1999-2000 school year, only 5.6 % indicated that they would prefer a career in engineering and a mere 0.8% were majoring in mathematics. Contrast this with 17.6% of the undergraduates working toward a career in the arts and humanities and 18.6% in business and management (Young & Bae, 1997).

At the graduate level, more and more foreign students are entering universities in the United States to pursue degrees that require high spatial abilities. At U.S. institutes of higher learning in 1994, 12% of all master's degrees and 27% of all doctorate degrees were earned by students from foreign countries. While foreign nationals earned just over a quarter of the doctoral degrees in the United States, they earned a much higher percentage of degrees in mathematics and engineering. A total of 49% of the mathematics doctorates and 53% of engineering doctorates conferred in the US were earned by students from foreign countries, and the combination of the fields of science and engineering results in an even bleaker picture for Americans. In 1994 U.S. doctoral recipients comprised 32% of the doctorates conferred in science and engineering and foreign recipients earned 61% of the degrees (Young & Bae, 1997). Our increasingly technological world requires that American students obtain a solid background and encouragement in areas such as science, engineering, and mathematics to keep pace with our culture (Shea, et at., 2001). The statistics suggest American students are not pursuing higher education in these critical disciplines.

Occupations that rely on spatial reasoning such as engineering, cartography, architecture, physics, chemistry, and medical surgery are associated with cognitively demanding educational tracks. A comparison of people identified as gifted in spatial ability with individuals equally gifted in mathematics and verbal ability found that the spatial group was disproportionately undereducated and underemployed (Gohm et al., 1998). Failure to identify and nurture the strengths in children with spatial gifts not only does a disservice to the children involved but also to our society (Shea et al., 2001). The strengths of spatial learners – the ability to grasp complex systems, ease in discovering relationships, and high levels of creativity and originality - are prerequisites for contributions of new knowledge and unique problem solutions.

Shea, Lubinski, and Benbow's (2001) longitudinal study assessing spatial ability in students who scored at the top 0.5% in general intelligences at age 13 on the SAT demonstrates the importance of identifying children with spatial talents. They found that verbal and quantitative abilities alone, the most frequently assessed areas of intelligence, were insufficient descriptors of intellectually talented students.

> This investigation uncovered a huge range in spatial ability among intellectually gifted students identified by conventional talent-search procedures.... An issue of particular concern is the likelihood that some intellectually promising students are not being identified by current practices, because of the lack of attention given to spatial ability....there are obviously large numbers of "high-space" (i.e., spatially talented) students who do not meet the minimum math or verbal criteria for participation in talent searches....Selecting for the top 3% of verbal-mathematical ability will result in the loss of more than half of the students representing the top 1% of spatial ability! (Shea et al., 2001, p. 612)

Identifying children with spatial gifts at a young age can help them to develop their talents and use them to their fullest potential. The educational system has an obligation to encourage students with spatial strengths, not only for the benefit of the individual student but also for the benefit of society.

Characteristics of Children with High Spatial Abilities

> We need to have special concern for children whose greatest strength is the grasp of complex structure. When these children have difficulty using conventions of detailed sequencing, their special knowledge tends not to be recognized by others, and they are frustrated in using their specialized giftedness. (Dixon, 1983, p. 116)

Spatial ability is closely related to visual thinking but is not a single entity; consequently, there is no one pattern of characteristics that will manifest itself in children with spatial gifts (Dixon, 1983; Olson, 1984). Combinations of the traits described vary widely from individual to individual. Puzzles, mazes, map reading, model building, tinkering, and craftwork are some of the activities in which these children who manipulate images in their minds excel (Mann, 2001; Olson; Silverman, 1989, 2002). Children with these skills are adept at dismantling mechanical devices and often discover a better way to put them back together. Legos™, Construx™, K'nex™, Tinker Toys™, and Erector Sets™ are often favorite toys of spatial children as are the boxes in which they are packaged. Their creativity results in their use and manipulation of toys in new and unique ways. These students may display an inability to concentrate on verbal information and exhibit a poor sense of the passage of time, especially when they are involved in their area of passion or play with their favorite toys.

At school, students with spatial gifts struggle to master material requiring rote memorization, yet thrive when involved in situations requiring higher order thinking skills and creative problem solving (Baum, 1984). A child with spatial strengths may have difficulty if asked to memorize the names and the dates of the battles of the Civil War but may excel in understanding the causes of the war, the impact specific battles had on the outcome of the war, and how America's Civil War compares and contrasts to civil wars in other nations. A student with spatial talents may struggle with mathematical computation but be able to solve abstract math problems with ease. He or she may verbalize highly creative stories but be unable to transfer the story into the written word (Silverman, 1989, 2002). Reading aloud may not be a good indicator of a spatial learner's reasoning abilities as oral reading may be laborious, while silent reading may result in a high level of comprehension (Mann, 2001).

Spatial learners tend to process information more slowly and their high level of internal mental activity may be interpreted as intentional off-task behavior or daydreaming (Dixon, 1983; West, 1991). In reality, spatial learners may have to consider the entire concept and reflect on how individual pieces fit into the main scheme of information as they are holistic in their approach to learning (Silverman, 1989, 2002); they may have difficulty attending to details that are presented in isolation. They often display an ability to grasp complex rela-

Possible Strengths and Weaknesses of Spatial Learners

Area of Strength	Perceived Weakness
Grasps relationships between systems	Has difficulty grasping isolated details
Excels with complex, higher level content	Struggles with easy or basic content
Is reflective	May be seen as a daydreamer
Has excellent memory for specific information	Has difficulty with rote memorization
Is preoccupied with ideas	Possesses weak social skills
Is able to manipulate visual images	Processes verbal communication slowly
Exhibits creative talent	Struggles in traditional academic settings
Excels at mathematical concepts	Has poor mathematical computation skills
Uses metaphoric language effectively	Rarely uses concise descriptions in language
Has strong reading comprehension skills	Has weak reading decoding skills
Is aware of physical properties and patterns	Is slow to process conventional understandings
Possesses a vivid imagination	Has difficulty putting stories into written form

(Dixon, 1983; Silverman, 1989, 2002; West, 1997)

Table 1

tionships between systems, are aware of physical properties and patterns (Dixon) and understand how the pieces fit together. This holistic preference for acquiring knowledge may result in a weakness to plan sequentially.

Students with spatial strengths that are nurtured and encouraged often pursue careers that fit their unique abilities and enable them to excel in fields such as architecture, engineering, art, mechanics, computer science, mathematics, and science.

Spatial learners often demonstrate a confusing mixture of strengths and weaknesses, as suggested in Table 1. Language is a sequential process that may present the spatial learner with significant difficulties. The English language presents particular problems as it has little phonetic consistency, and the exceptions to the rules of English can turn the learning process into a memorization nightmare, which can overwhelm a student who seeks patterns and connections (Dixon, 1983). Educators need to be aware of the language issues that can be problematic for students with spatial strengths and offer them counseling that moves them in the direction of careers that value their special abilities. Students with spatial strengths that are nurtured and encouraged often pursue careers that fit their unique abilities and enable them to excel in fields such as architecture, engineering, art, mechanics, computer science, mathematics, and science. These areas all require the abilities characteristic of individuals who possess spatial strengths (Baum, Dixon, & Owen, 1991; Dixon; 1983; Silverman, 2002; West, 1991).

Identification of Spatial Ability

> Central to spatial intelligence are the capacities to perceive the visual world accurately, to perform transformations and modifications upon one's initial perceptions, and to be able to re-create aspects of one's visual experience, even in the absence of relevant physical stimuli. (Gardner, 1983, p. 173)

Identification of spatially gifted children presents a unique set of challenges (Olenchak & Reis, 2002), as achievement tests commonly used as assessments in schools rarely include a nonverbal component. Spatial ability is not easily expressed in verbal terms or demonstrated on pencil and paper tasks (Olson, 1984), and is therefore difficult to evaluate on group assessments administered on a large scale. The Weschler Intelligence Scale for Children (WISC; Wechsler, 2003) can be a valuable tool for identifying children with spatial strengths. When using this assessment tool, it is advisable to carefully consider all subtest scores, in addition to the Full Scale score (Olenchak & Reis). The Block Design subtest has been determined to be an accurate indicator of a child's spatial tendencies (Baum, Dixon, & Owen, 1991; Beckman, 1977; Dixon, 1983.) In research conducted with students who scored 17 or more on the Block Design subtest of the WISC, Beckman (1977) found a high correlation between the subtest scores and the profound intellectual thinking required of mathematics and science. Although high scores on certain subtests may indicate that a child has spatial strengths, Silverman (2002) found that many spatial learners are overlooked due to the fact that certain subtests on the WISC are timed and their slower processing speeds proved to be an obstacle, resulting in a lower overall Full Scale score.

The Wechsler Intelligence Scale for Children was revised and renormed in 2003. In addition to providing a composite score representing a child's general intellectual ability, it also provides indices in Verbal Comprehension, Perceptual Reasoning, Working Memory, and Processing Speed. The Perceptual Reasoning Index (PRI) "is a measure of perceptual and fluid reasoning, spatial processing, and visual-motor integration" (Wechsler, 2003, p. 104). The subtests that comprise the PRI are Block Design, Matrix Reasoning, and Picture Concepts. The addition of Matrix Reasoning, which was not included in previous versions of the WISC, provides a reliable measure of visual information processing and abstract reasoning skills. This subtest along with Block Design and Picture Concepts may lead to more accurate identification of visual spatial learners.

The discrepancies between scores on the WISC subtests or between the Verbal Comprehension Index and the Perceptual Reasoning Index, with the PRI being the higher score, may indicate that the child has a strength in nonverbal abilities that is being overshadowed by a weakness in verbal abilities. The resulting lower Full Scale score on the WISC for students with spatial strengths and weak sequential skills causes them to be denied access to gifted services, and their strengths result in scores too high for identification for learning disability services.

Not every child can take a WISC or other tests with nonverbal components, and therefore, a more practical approach in the process of identifying gifted spatial learners may involve a consideration of other indicators of spatial giftedness. In order for an assessment to be valid, multiple criteria should be used in the identification of gifted children with spatial strengths. Examination of students' preferred methods of acquiring new knowledge and choice of activities, both in the classroom and especially at home, can help to identify children with spatial strengths.

A Learning Disability or a Learning Difference?

Not all students who have high spatial ability are learning disabled and not all learning disabled children have high spatial ability. Students who have high scores on the Perceptual Reasoning Index of the WISC-IV–Picture Concepts, Block Design, and Matrix Reasoning – can be categorized as talented spatial learners. Whether or not the child manifests characteristics of a learning disability depends upon the extent of the discrepancy between scores in the spatial category and the obtained scores on the subtests of the Verbal Comprehension Index. If a child's scores are similar in the nonverbal and verbal domains, he or she should exhibit a balance of strengths in the two areas. With strong spatial or nonverbal skills and equivalent abilities in the sequential or verbal arena, these students are less likely to experience the school difficulties of the child with spatial strengths and sequential weaknesses.

The National Association for Gifted Children's (NAGC) policy statement defines students with concomitant gifts and learning disabilities as follows:

> These students exhibit characteristics of both exceptionalities: giftedness and learning disabilities. Their gifted behaviors often include keen interests, high levels of creativity, superior abilities in abstract thinking, and problem-solving prowess...they frequently display problems in one or more of the following: reading, writing, mathematics, memory, organization, or sustaining attention. (NAGC, 1998, p. 1)

With strengths in the areas of creativity, abstract thinking, or problem solving and weaknesses in rote memorization, organization, writing, or possibly reading and mathematics computation, gifted children with spatial strengths and sequential weaknesses meet the criteria in the description of gifted/learning disabled students proposed by the NAGC.

It is disconcerting to be able to understand the latest scientific discovery about novas as presented in *Scientific American* and to be receiving low grades in school due to misspelled words and poorly organized written assignments.

Some would argue that highly spatial children do not have a learning disability but simply have a different style of learning (Dixon, 1983; West, 1991). What is considered a handicap in a sequential educational environment may actually be the outward manifestation of a significant strength in a different mode of thinking. The gift may be regarded as a problem rather than an asset (West). Rather than focusing on the apparent defect in an individual, educators should look for a proficiency in an opposing skill (Holton, 1972). When identifying a perceived learning disability, professionals should also work to identify an area of strength that may be displacing the weak academic area and in some cases masking the disability.

Whether or not a child's spatial strengths coupled with sequential weaknesses are identified as a learning disability or a learning difference, the needs of the child must be addressed. The educational environment must be supportive and should concentrate on identifying and nurturing the student's strengths. "When those closest to them honor their strengths and believe in their ability to fulfill their dreams, they're able to mobilize their will to succeed against all odds" (Silverman, 2002, p. 191).

Emotional Concerns

Feeling competent in areas of interest and incompetent in areas of academic expectations can leave a gifted spatial learner confused (Olenchak & Reis, 2002) and feeling like a fraud. It is disconcerting to be able to understand the latest scientific discovery about novas as presented in *Scientific American* and to be receiving low grades in school due to misspelled words and poorly organized written assignments. Self-understanding is essential for children with spatial strengths and sequential weaknesses (Dixon, 1983; West, 1997). An awareness of strengths and the value of those strengths both personally and culturally may help parents and teachers to alleviate a child's frustration. A thorough understanding of the subjects and skills that will require intense effort to master, along with the knowledge that it is not their "fault" that they struggle in these areas, will improve their self-concepts and self-acceptance. Their areas of difficulty and areas of excellence should be explained to them as early as possible and should be reinforced on a regular basis (Dole, 2001).

Children with spatial gifts need to be engaged and appreciated in an environment in which they feel comfortable and unthreatened (Dixon, 1983). As with other gifted children, they may have a heightened sensitivity that allows them to quickly perceive an adult's ambivalence and anxiety (Silverman, 2002). The emotional responses to seemingly benign comments may result in loss of motivation or self-esteem, reluctance to engage in classroom activities and other behavioral changes (Yates, Berninger, & Abbott, 1995).

Supporting spatially talented gifted students may be best accomplished through mentorships with appropriate mentors, such as architects, engineers, inventors, and computer programmers. Albert Einstein, for example, was fortunate to have a supportive family and encouragement from a medical student who had dinner with the family on a weekly basis. Working with an adult who has succeeded in an area that interests the student may help the child to recognize the value of his own gifts and may give him confidence to pursue his passions.

The sequential structure of many American classrooms may place an additional burden on learners with spatial strengths as they struggle to adapt to classroom expectations. Several teaching strategies may help to support children with spatial strengths (see Table 2).

An emphasis on concept learning may be beneficial, as a child with spatial talents needs to "see the whole picture." Many can excel when they deal with entire systems. Explaining major concepts so that the child has an understanding of the instructional goal will help him or her to fit the pieces of the puzzle together as the class progresses through a new unit (Mann, 2001).

The gifted spatial learner may benefit from opportunities to work with complex material requiring creativity and higher order thinking skills (Baum & Owen, 1988; Silverman, 1989). Learning environments that encourage students to problem solve, look for abstract relationships, and use inductive reasoning skills may enable spatial learners to thrive (Silverman, 2002). If these opportunities are provided in the child's area of interest, the learning may be even more effective. Gifted children with spatial strengths and sequential weaknesses must have their strengths recognized and

Teaching Strategies for Spatial Learners

Effective Teaching Strategies	Less Effective Teaching Strategies
Concept learning	Rote memorization
Reflection	Rapid recall of information
Discovery learning	Lecture and oral directions
Reading instruction emphasizing sight words	Reading instruction emphasizing phonics
Activities using manipulatives	Drill and repetition
Interdisciplinary units	Step-by-step learning
Open-ended problem solving	Note taking and outlining

Table 2

nurtured (Baum & Owen, 1988; Dixon, 1983; Mann, 2001; Olenchak & Reis, 2002; Robinson, 1999). Minimizing the amount of time spent in areas of deficiency and maximizing the time spent in their area of passion have been shown to have a possible indirect effect on improving the child's weaknesses (Baum & Owen, 1988). As the child works through a high-level project, the basic skills necessary to accomplish the end product will be integrated into learning opportunities. If a child struggles to read, the need to locate material in his or her area of interest and the passion for the topic can help to encourage the child to create sense out of the figures on the page that are words. If a child has difficulty learning math facts but is passionate about sports, he or she can develop a project that uses statistics, using the facts enthusiastically.

Too much of an emphasis on verbal communication in lectures can be difficult for students with spatial strengths and sequential weaknesses. It has been proposed that, rather than thinking in words, the spatial learner thinks in pictures. It takes time to translate the spoken word into images and by the time the image has been created and absorbed, the lecturer has often moved on to a new topic (West, 1991). Pausing frequently while lecturing or giving instructions to a class provides the spatial learner time to transpose the verbal messages into meaningful diagrams. When a spatially talented child is asked to respond to a question, it can take quite some time for the answer to be formulated. The child must first translate the question into an image, then create an answer in the form of an image, then translate this newly created picture back into words (Silverman, 2002). Spatial learners may have trouble speaking on demand, yet have little difficulty with "spontaneous language," or language that he initiates himself (West).

Activities designed to incorporate the child's personal experiences and emphasize the student's strengths tend to enhance the student's motivation (Dixon, 1983; Robinson, 1999). Differentiating the curriculum for gifted children with spatial talents by minimizing rote learning and maximizing the conceptualization of ideas may lead to academic gains as well as social and emotional improvement (Olenchak & Reis, 2002). These social, emotional, and academic improvements can help pave the way for these highly capable children to develop personal satisfaction and become valuable contributors to society.

Where Do We Go From Here?

The identification and education of gifted spatial learners is an area in which a scarcity of research exists. A variety of identification procedures used to locate these children should be analyzed in an effort to determine which systems are feasible and accurate. Differentiated curricula should be developed and evaluated utilizing empirical research methods. The field would benefit from longitudinal studies of gifted children with spatial strengths to determine what factors contribute to their successes and frustrations. An evaluation of high ability students who are underachieving to determine what percentage of those children are spatially gifted students may help justify supporting special programming services. An analysis of successful adult problem solvers could help to determine if they have more prominent spatial abilities or verbal abilities. If spatial skills are present, educators must ask if they are selecting all of the talented children who can benefit from gifted programs at the elementary and secondary school level. Society needs the talents of gifted children with spatial strengths at the highest levels of the professional world (Gohm et al., 1998). It is essential that future research examine ways that we can best support these children and their families in their education and their healthy social and emotional growth. Without this intervention, spatially gifted children may not realize their full potential in the predominately sequential American school system. This unique population may be at risk for underachievement and underemployment, which could lead to a critical shortage of talents in the next generation. After all, it is from this group that our next generation of Picassos and Edisons will emerge.

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