Chapter 6
What Innovations Have We Already Lost?: The Importance of Identifying and Developing Spatial Talent

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6.1 Introduction

We wanted flying cars, instead we got 140 characters. – Peter Thiel

In 1921, Lewis Terman initiated a talent search (Holahan and Sears 1995; Terman 1925) to find some of the brightest children in the U.S. His search for these "Termites" would identify a wide range of people, including some who would go on to be famous. These included kids who would become the educational psychologist Lee Cronbach and the creator of the TV show I Love Lucy Jess Oppenheimer. But there were two young boys who were not identified as gifted but eventually won the Nobel Prize in physics. Their names were William Shockley and Luis Alvarez and the scientific area in which they achieved their fame was arguably heavily visual-spatial in nature. Why were two Nobel winners missed? Likely because Terman had used the highly verbal Stanford-Binet, which did not include a sufficient spatial measure.

Peter Thiel (2015) famously said of the future: "We wanted flying cars, instead we got 140 characters." As innovative as Twitter might be, it pales in comparison to engineering feats that could truly transform our future. Think, for example, of the things Elon Musk has been dreaming about: the Hyperloop, a Mars colony, or a new energy source (Vance 2015; Wai 2015a). Vance (2015, book jacket) describes Musk as a "modern day alloy of Thomas Edison, Henry Ford, Howard Hughes, and Steve Jobs" – someone who has a mind like a computer and the ability to endure failure in his quest to change the world through his companies. As Dolly Singh, former head of talent acquisition for Space-X, told Vance (p. 220): "We *were looking for people*

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M.S. Khine (ed.), *Visual-spatial Ability in STEM Education*,
DOI 10.1007/978-3-319-44385-0_6

that had been building things since they were little." In essence, these are driven people who have extraordinary spatial talent, defined as "the ability to generate, retain, retrieve, and transform well-structured visual images" (Lohman 1996, p. 1000). But the people who have made it through the talent filter of one of Musk's companies are those who succeeded in overcoming many earlier educational and occupational hurdles. They are the students who had enormous opportunity to develop their spatial talent and succeed in traditional school systems that value students who are good at reading, writing, and doing math. For some of those spatially talented students that made it, they may have had parents to encourage those visual talents, even if school did not. They also may have had extremely high math and verbal abilities in addition to their high spatial ability, which allowed them to perform well in school even those weren't their primary strength. These individuals talented in all aspects may be more the exception than the rule, however, as people often favor either spatial or verbal ability (Humphreys et al. 1993) – even gifted individuals (i.e., those scoring in the top 1 % of cognitive ability). The average correlation between measures of phonological fluency and spatial aptitude is 0.4, meaning these capacities can develop unevenly – although it is certainly possible to score high on tests of both (Lohman 1994b; for a more technical discussion of ability intercorrelations see Kell and Lubinski 2013). Indeed, 70 % of individuals scoring in the top 1 % on spatial ability tests do not score in the top 1 % of verbal or math ability tests (Wai et al. 2009a). Further, spatially-gifted individuals seem to be relatively less able in terms of fluency and phonological word encoding, rather than verbal ability overall, with many exhibiting language delays or disabilities (Lohman 1994a, b). The implication is that there is a large population of spatially talented but less verbally and mathematically talented students who are not identified and therefore their talent is unlikely to be fully developed. *In fact*, *many standardized tests in schools today lack spatial measures*, and this means many spatially talented students are not being identified, and their talent is therefore unlikely to be fully encouraged or developed. Just how many Nobel Prize winning scientists or spatial innovators have we let fall through the cracks?

There is a large body of evidence linking spatial ability to educational-occupational outcomes (e.g. Gohm et al. 1998; Humphreys et al. 1993; Lohman 1994a, b, 1996; Smith 1964). However, this chapter focuses on a research study linking over 50 years of data to show that spatial ability in addition to math and verbal ability has predictive power in science, technology, engineering, and mathematics (STEM) domains (Wai et al. 2009a). Next, the issue of spatial ability training (e.g., Uttal et al. 2013a, b) and females in STEM are discussed. Then, how these findings and other research can be translated into education practice is presented (Wai et al. 2009b; Wai and Worrell 2016). Finally, a discussion of the broader societal implications of neglecting spatially talented students will be laid out (Wai 2013, 2015a). For example, how many innovations have we already lost because we have not adequately identified and developed the talent of some of our most promising innovators?

6.2 Historical Background

Spatial reasoning is associated with success in tasks classified as manual, mechanical, and practical (Carroll 1993; Hegarty 2004; Vernon 1950) thus by implication spatial ability's importance has been recognized for over 2000 years. Unfortunately, the history of prioritizing verbal and mathematical abilities over spatial ability is just as long. In Hellenic Greece and Medieval Europe, the physically-grounded mechanical arts (e.g., weaving, agriculture, masonry) were considered "illiberal", to explicitly contrast them with the intellectually-grounded "liberal arts" (e.g., grammar, logic, rhetoric) (Whitney 1990). This division continued through the Renaissance and into the Enlightenment – and was inveighed against in the first modern encyclopedia, where it was stressed that the liberal and mechanical arts should be considered on the same plane (Applebaum 1992; Diderot 1751/1992). Attitudes toward practical work were more positive in the early United States, where the Morrill Act of 1862 put aside land for the founding of major universities specifically emphasizing the teaching of "such branches of learning as are related to agriculture and the mechanic arts" (§ 304).

The nineteenth century also saw the beginning of modern psychology and the first scientific study of concepts related to spatial ability. Itard (1774–1838) and Seguin (1818–1880) devised form boards (now recognized as spatial skill measures) to facilitate the education of individuals with mental retardation (Sylvester 1913) while pioneers of psychology such as Galton (1880), James (1890), and Wundt (1896) all investigated or acknowledged mental imagery explicitly. Alfred Binet (1892) argued in favor of the existence of visual imagery and, as co-creator of the first intelligence test (Binet and Simon 1905), it contained items tapping spatial ability – as did many of its immediate American descendants (e.g., Goddard 1910; Terman 1916). Many mechanical and hands-on tasks were developed in the 1910s (e.g., Pinter and Paterson 1917) and by the 1920s scores on spatial tests were being used for a wide variety of purposes, including making decisions for awarding scholarships and personnel selection (Smith 1964; Viteles 1932); spatial tasks were even used to assess the mental capabilities of immigrants arriving at Ellis Island (Knox 1914; Richardson 2003).

Measurement of spatial ability has an especially long-standing history in the United States military. The Army Beta test, used to evaluate the mental competence of illiterate or non-English-speaking soldiers for service in World War I, included spatial items, as did the Army General Classification Test used in World War II (Humphreys and Lubinski 1996; Thorndike and Lohman 1990). The current entrance battery used in the United States military (Armed Services Vocational Aptitude Battery [ASVAB]) measures spatial ability through the Assembling Objects (AO) test – but AO scores are not included in the composite score (Armed Forces Qualifying Test) actually used to select soldiers in any branch of the military and only used for classification in the Navy (National Research Council [NRC] 2015). The NRC (2015) has recommended, however, that more attention be paid to spatial ability for the purposes of predicting performance.

6.3 The Importance of Spatial Ability for STEM Education and Occupations Across Half a Century

In this section, a number of prior studies and datasets that span over 50 years will be discussed to show the importance of spatial ability for STEM domains. These include a National Science Foundation report and review of the literature for pre-1957 (Super and Bachrach 1957), a stratified random sample of the U.S. 9th through 12th grade population spanning 1960–1974 (Project Talent; Flanagan et al. 1962; Wise et al. 1979) and data on the top 1 % of cognitive ability from the Study of Mathematically Precocious Youth spanning 1971 to the present (SMPY; Lubinski and Benbow 2006; Shea et al. 2001). Next, an examination within Project Talent data looking at earned degrees and the pattern of specific abilities compared to the general population and each other will be discussed. The section will conclude with a longitudinal examination of students in the top 1 % of spatial ability who were not in the top 1 % of math or verbal ability. This will constitute a concise summary of Wai et al. (2009a) which should be read in full for readers interested in technical details.

Over a half century ago, Super and Bachrach (1957) published a report titled *Scientific Careers*, in which they discussed the role of spatial ability in the eventual development and performance of individuals in STEM domains. This National Science Foundation report reviewed the literature to date, concluding that both mathematical and spatial reasoning were important for STEM and that "Longitudinal studies beginning at a relatively early age and extending over a period of some 10–15 years seemed called for" (p. 87).

Figure 6.1 shows longitudinal data from SMPY (Shea et al. 2001) illustrating how spatial ability, even over and above math and verbal ability, is associated with STEM disciplines and adds incremental validity in the prediction of educational and occupational criteria, even within a sample in the top 1 % of general cognitive ability. For example, each of the panels in Figure A illustrate math ability on the x-axis, verbal ability on the y-axis, and spatial ability on the z-axis for various major/occupational groups for four outcome variables: favorite high school course (Panel A), least favorite high school course (Panel B), college majors (Panel C), and occupation (Panel D). In order to explain how to read these graphs let's look at Panel C which shows various college majors, and specifically at engineering, electrical. Because that group is to the right of the origin this group has above average math ability relative to other groups. Because that group is below the origin this group has below average verbal ability relative to other groups. And because there is a relatively long arrow extending to the right from that group's location, this means this group has above average spatial ability relative to other groups. Now if we look within Panel C at humanities, we see the opposite pattern: below average math ability and spatial ability and above average verbal ability. For clarity, the STEM groups are within dotted line boxes, and what can be seen across all four panels is that within the SMPY sample, across high school course preference, college major, and

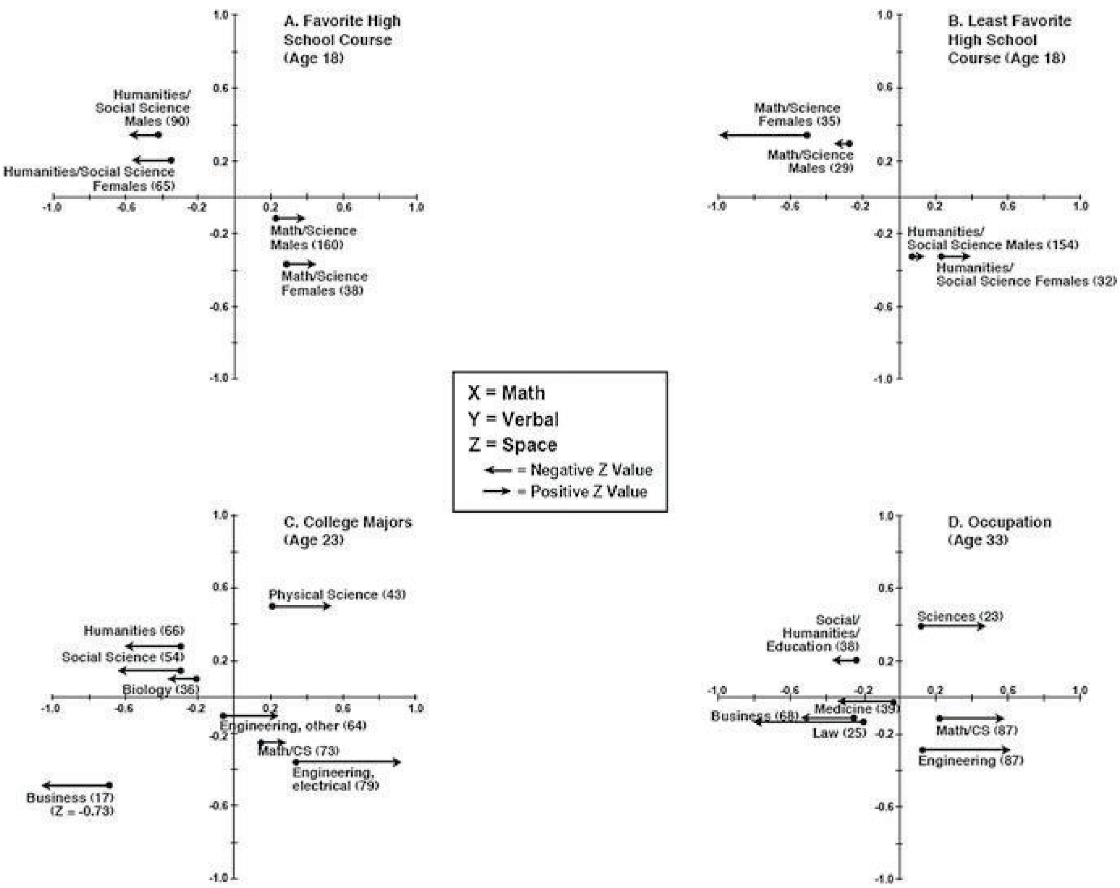

Fig. 6.1 Longitudinal data from SMPY
Shown are trivariate (X/Y/Z = Mathematical/Verbal/Spatial) means for (Panel **a**) favorite and (**b**) least favorite high school course at age 18, (**c**) college majors at age 23, and (**d**) occupation at age 33. Mathematical, verbal, and spatial ability are on the x-, y-, and z-axes respectively (*arrows* to the *right* indicate a positive z value; *arrows* to the *left* indicate a negative z value). Panels (**a**, **b**) are standardized within sex; Panels (**c**, **d**) are standardized across sexes. For Business in Panel (**c**), note that the length of the *arrow* is actually z = –0.73. *CS* computer science (Figure adapted from Shea et al. (2001). Copyright © 2001 by the American Psychological Association. Reproduced with permission)

occupation, the STEM domains tend to have higher spatial ability relative to the other groups.

Figure 6.2 shows longitudinal data from Project Talent (Wai et al. 2009a), a stratified random sample of high school students who were followed up 11 years after their graduation. At that time, their educational degrees and occupational status was assessed. Panel A shows terminal bachelors (i.e. a bachelors degree was their highest degree), Panel B shows terminal masters, Panel C shows doctorates, and Panel D shows occupations. Similar to Fig. 6.1, math, verbal, and spatial ability are plotted on the x-, y-, and z-axes respectively, and group means are relative to all other groups within each sample. Once again, across each of these panels, the STEM groups had relatively high spatial ability compared to the other groups. This replicates the findings from SMPY, a sample in the top 1 % in ability, within a stratified random sample of the U.S. population.

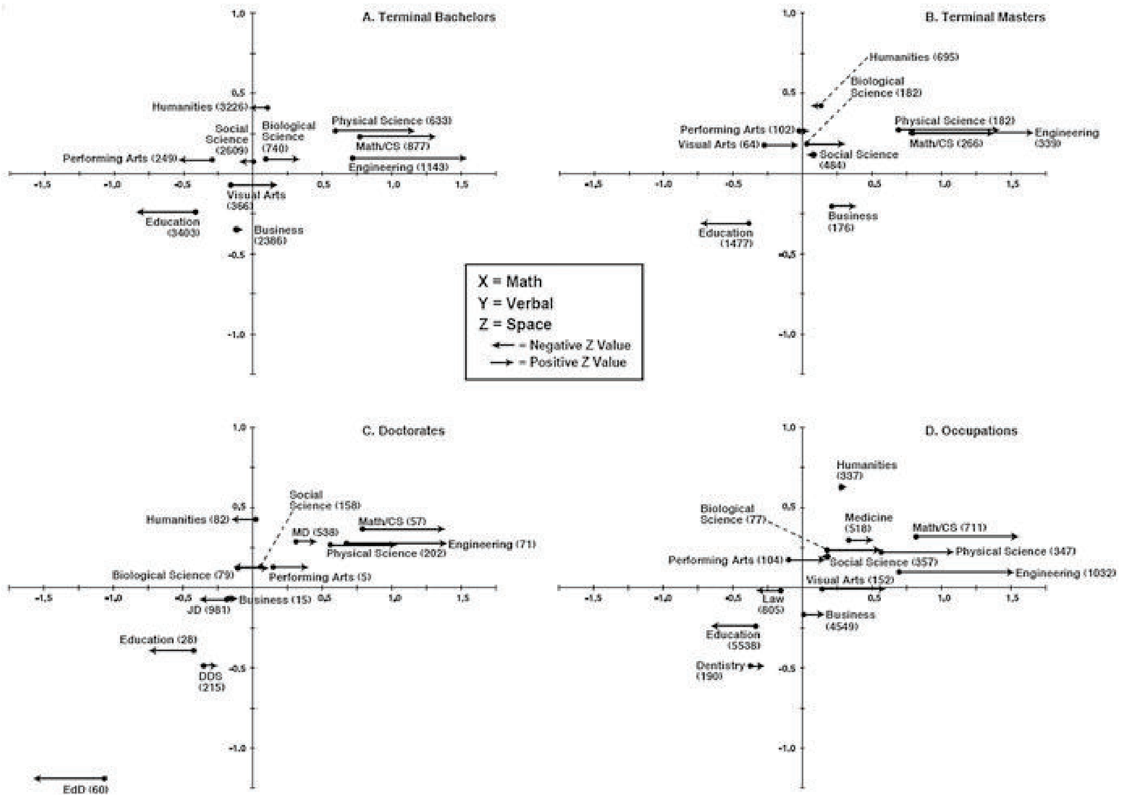

Fig. 6.2 Longitudinal data from Project Talent (1)
Trivariate means for Panel (**a**) bachelors, (**b**) masters, (**c**) doctorates, and (**d**) occupations of those individuals whose data were included in Panels (**a–c**). Panels (**a**) through (**d**) are standardized across sexes. Mathematical ability is on the x-axis, and verbal ability is on the y-axis; an *arrow* from each group mean indicates either positive (to the *right*) or negative (to the *left*) spatial ability. Breakdowns by sex are reported in Appendix B of Wai et al. (2009a). *CS* computer science (Data are from Project Talent (Figure adapted from Wai et al. 2009a. Copyright © 2009 by the American Psychological Association. Reproduced with permission)

Figure 6.3 also shows longitudinal data from Project Talent (Wai et al. 2009a), looking at terminal bachelors, masters, and PhDs by field. Instead of from a within groups perspective (see Fig. 6.2), it compares each of the groups to each other and to the general population on verbal, spatial, and mathematical ability as well as general ability (verbal + spatial + math). General ability is shown along the x-axis and specific ability pattern is shown along the y-axis each in z-score or standard deviation units. The first important thing to note is that each of these groups is well above average relative to the general population. For example, education (the lowest group) is over 0.5 standard deviations above average and the traditional STEM groups (math/CS, physical science, and engineering) are over 1.25 standard deviations above average (this pattern has been found for decades, for a review see Wai 2015b). This also shows there is a large average difference in general ability level across different groups. However, when we examine the specific ability patterns, the

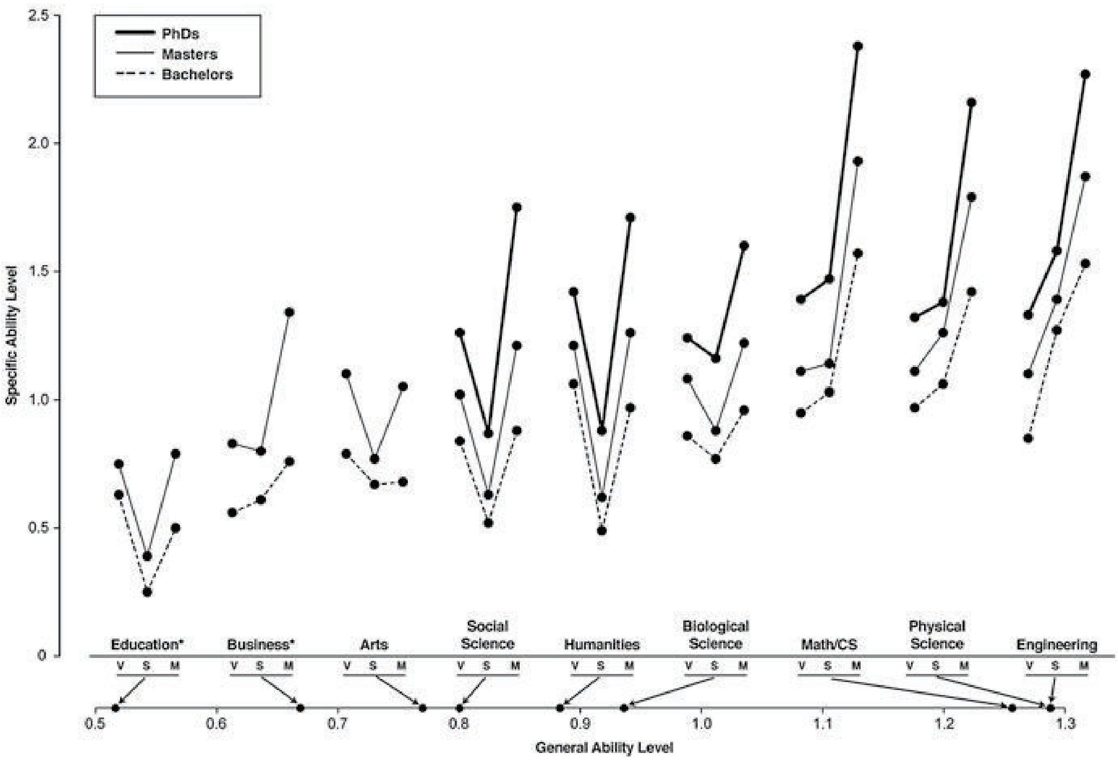

Fig. 6.3 Longitudinal data from Project Talent (2)
For education and business, masters and doctorates were combined because the doctorate samples for these groups were too small to obtain stability (n < 30). For the specific n for each degree by sex that composed the major groupings, see Appendix A of Wai et al. (2009a, b). Average z scores of participants on spatial, mathematical, and verbal ability for bachelor's degrees, master's degrees, and PhDs are plotted by field in Figure 3. The groups are plotted in rank order of their normative standing on g (verbal [V] + spatial [S] + mathematical [M]) along the x-axis, and each *arrow* indicates on the continuous scale where each field lies on general mental ability. All x-axis values are based on the weighted means across each degree grouping. This figure is standardized in relation to all participants with complete ability data at the time of initial testing. Respective ns for each group (males + females) were as follows (for bachelor's, master's, and doctorates, respectively): engineering (1143, 339, 71), physical science (633, 182, 202), math/computer science (877, 266, 57), biological science (740, 182, 79), humanities (3226, 695, 82), social science (2609, 484, 158), arts (615, masters + doctorates = 171), business (2386, masters + doctorates = 191), and education (3403, masters + doctorates = 1505) (Figure adapted from Wai et al. 2009a. Copyright © 2009 by the American Psychological Association. Reproduced with permission)

first thing to note is how general ability rises as we go from bachelors to masters to doctorates within each group (which is indicated by the dotted lines being below the solid lines being below the bolded lines within each field. Next, it's important to emphasize that the STEM fields have both spatial and mathematical ability higher than all other groups, but it's interesting to note that even their verbal ability is higher than that of other groups. Across the data reviewed in Super and Bachrach (1957) and in Figs. 6.1, 6.2, and 6.3, we can clearly see that spatial ability has operated consistently in predicting STEM outcomes for the last 50 or more years.

6.4 The Importance of Spatial Ability for STEM Creativity

Long-standing anecdotal claims about the role of spatial ability in making scientific breakthroughs hint at its importance extending beyond traditional educational and career outcomes and into the creative realm: Einstein, Faraday, Maxwell, and Tesla all reported that spatial imagery was critical to the formulation of their ground-breaking ideas (Lohman 1994a; Shepard 1978; Uttal et al. 2013a, b). Empirically, however, establishing spatial ability as a predictor of creative achievement in STEM is difficult. First, in order for people to be identified as creative they must *produce* something judged to be creative (Vernon 1989). This is a rare feat in fields as challenging as STEM (Wai et al. 2009a, b), meaning its base rate in the general population is low and necessitating large samples in order for a consistent (i.e., non-chance) association to be identified (Ackerman 2014; Meehl and Rosen 1955). Second, a long period of time is likely required between the assessment of individuals' spatial skills and the gathering of information about their creative products, as developing the content mastery and expertise necessary to make significant creative contributions is time-consuming (formalized as the "10-year-rule"; cf. Simonton 1991, 2003) – and also to remove the threat of reverse causality of some of the spatial skills developed in the process of creating those products influencing individuals' performance on the spatial ability test itself (Heckman and Kautz 2012). Third, in order to establish not only a link but also a *unique* link (i.e., incremental validity; Sechrest 1963) between spatial ability and STEM creativity, measures of cognitive abilities other than spatial ability are required, as the correlation among specific abilities could lead to STEM accomplishment being mistakenly linked with spatial ability when the association is contingent on a different ability (e.g., mathematical). A recent follow-up of the SMPY cohort featured in Shea et al. (2001) met these requirements.

Kell et al. (2013) studied the creative products of Shea et al.'s (2001) sample of 563 participants 35 years after their identification, when they were approximately 48 years old. They defined an accomplishment as "creative" in the terms set forth by Simonton (2012) and derived from the United States Patent Office: It is deemed novel, useful, and surprising (i.e., not obvious) by expert judges (e.g., patent reviewers, peer referees). They gathered information on participants' patents ($n=33$) and peer-reviewed articles, the latter of which they sorted into three categories: arts/humanities/law/social sciences ($n=27$), biology/medicine ($n=35$), STEM ($n=65$). Using the three ability scores obtained when participants were 13 years old, they used a two-step discriminant function analysis (DFA) to examine the extent to which the cognitive abilities accounted for variation among the four criterion groups. Entered at Step 1 of the DFA, mathematical and verbal scores accounted for 10.5 % ($p<0.01$) and when spatial ability was entered at Step 2 it accounted for an incremental 7.5 % ($p<0.01$) of the variance (18 % total). Further, the pattern observed in Shea et al. (2001) and Wai et al. (2009a, b) for educational and career outcomes was repeated for the creative accomplishments: Individuals holding patents or STEM publications exhibited ability profiles typified by spatial > verbal scores, while those holding publications in the arts/humanities, law, or the social sciences had profiles characterized by verbal > spatial scores (see Kell et al. 2013, Figure 1, p. 1834).

6.5 What Happens to People in the Top 1 % in Spatial Ability Who Are Not in the Top 1 % of Verbal or Math Ability?

A full 70 % of the top 1 % in spatial ability is not in the top 1 % of math ability or verbal ability based on population level analyses within Project Talent (Wai et al. 2009a; Webb et al. 2007). So these are essentially people who have the higher spatial and relatively lower math and verbal ability profile. In traditional talent searches, typically students with strengths in math and verbal ability are identified, and the schools are well equipped to provide challenge for students with these strengths, especially mathematical ability (Assouline et al. 2015; Lohman 2005), but likely less so for spatial ability (Wai 2012). Despite talent searches, teachers, parents, or others likely not identifying and hence not appropriately developing such spatial talent in the Project Talent sample, one interesting question is how these students who exhibit the high spatial but relatively lower math and verbal profile fare educationally and occupationally later in life. Figure 6.4 looks at STEM (top panel) and visual arts (bottom panel) degrees and occupations of that 70 % of the top 1 % that is lower in math and verbal ability. The sum of the black bars plus the gray bars for each category is the percentage of each group earning a specific outcome (e.g. for STEM male bachelors this was just over 15 %), whereas the black bars indicate the base rate in Project Talent for the respective grouping (e.g. for STEM male bachelors this was about 5 %), which indicates that relative to the base rate, these males earned STEM bachelors three times the base rate in the population. As can be seen across all other groupings, this pattern was found. Male and female comparisons in Project Talent are a bit dated, but are shown for descriptive purposes, so the main finding has to do with the overall pattern. Clearly there is a large pool of missed spatial talent that even though not being identified and having their talent developed properly as a group still goes on to accomplish highly in the STEM and visual arts disciplines. What more could they have accomplished if their talent was fully developed? Especially for females, this appears to be a missed opportunity to increase the STEM talent that so many U.S. reports have emphasized is needed (Miller et al. under review; PCAST 2012).

6.6 Spatial Ability Training and Females in STEM

A large number of researchers have targeted spatial reasoning training as a potentially fruitful area of research (Newcombe 2010; Miller and Halpern 2013; Uttal et al. 2013a, b; Sorby and Baartmans 1996, 2000), in part to potentially increase the

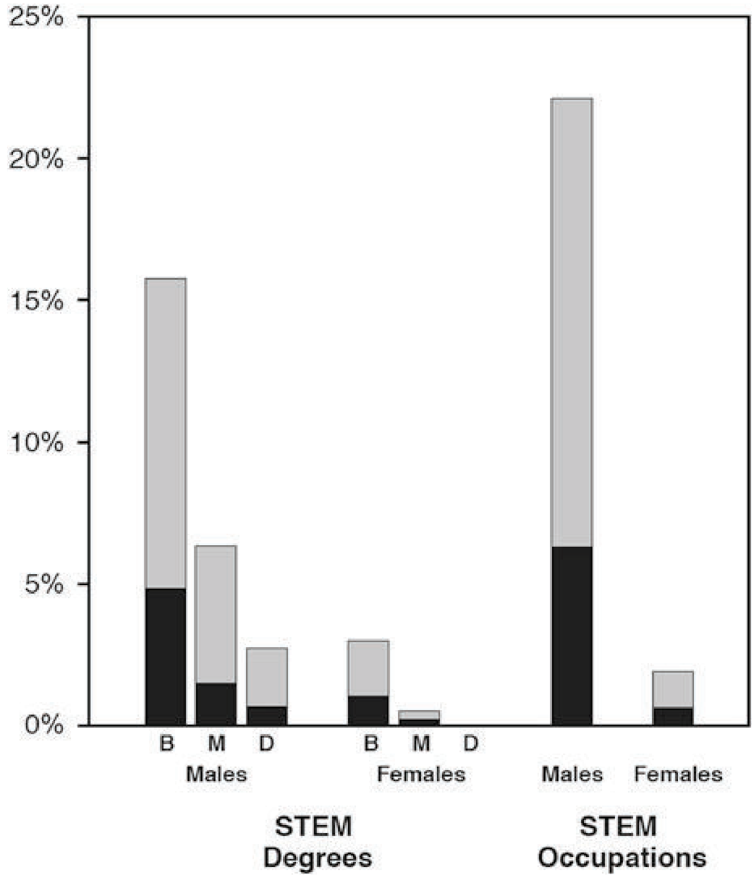

Fig. 6.4 Gender differences
The *top* panel includes (*left*) the proportion of the top 1 % in spatial ability who were not in the top 1 % in mathematical or verbal ability who earned STEM degrees and (*right*) occupations broken down by males and females, respectively. The *bottom* panel includes the proportion of this population who earned visual arts degrees and worked in related occupations. The *black bars* indicate the base rate in Project Talent for the respective grouping. *B* bachelor's degrees, *M* master's degrees, *D* doctorate degrees, *STEM* science, technology, engineering, and mathematics (Figure adapted from Wai et al. 2009a. Copyright © 2009 by the American Psychological Association. Reproduced with permission)

numbers of females in STEM fields but also to increase the number of STEM graduates generally. A major meta-analysis of spatial training studies by Uttal et al. (2013a, b) concluded that the average effect size for training relative to control was 0.47 (Hedges's g). And these findings are not just for the general population but also among gifted and largely STEM focused undergraduates (Miller and Halpern 2013). Uttal et al. (2013a, b, p. 352) concluded that "the results suggest that spatially enriched education could pay substantial dividends in increasing participation in mathematics, science, and engineering." Given the findings showing that a consistent STEM *educational dosage* or educational enrichment over a long period of time ends up predicting long-term educational and occupational outcomes (Wai et al. 2010), this may make sense and this area of research may be promising. However, it is important to make the distinction between training the *trait* of spatial ability and providing spatially enriched *education* to develop spatial modes of thinking in learning STEM or other subjects. At this point it appears that a number of experimental training studies show positive findings for training the trait of spatial ability, but not necessarily long-term evidence showing that this relatively short-term training is the *causal* mechanism that impacts later STEM educational and occupational outcomes as reviewed in this chapter (Wai et al. 2009a). Therefore, just as in other areas of training abilities, such as working memory or general intelligence (Melby-Lervåg and Hulme 2013; Shipstead et al. 2012), where the findings remain mixed despite a much larger literature devoted to the area, we don't know yet whether spatial training will pay significant dividends many years down the line and (if they do) exactly where. At the same time, for any students who have not been exposed to traditional spatial methods of thinking or hands on work, perhaps especially for females, familiarizing them with spatial modes of thinking and training those skills may be promising in increasing the number of females interested in pursuing STEM careers (Ceci and Williams 2010).

6.7 Spatial Talent Identification and Development

Given that the majority of standardized tests both in K-12 and those also used in college admissions and talent searches such as the Scholastic Assessment Test (SAT) and American College Test (ACT) don't include spatial measures, this means that spatially talented students are less likely to be identified as talented and therefore their talent is unlikely to be fully developed. Considering over half of the top 1 % in spatial reasoning abilities are currently being missed in modern talent searches (i.e., top 1 % in spatial but not in the top 3 % of math or verbal ability; Webb et al. 2007; Wai et al. 2009b), this means this population is definitely neglected in relation to other talented students, but also compared to students throughout the entire distribution of talent (Assouline et al. 2015).

6.8 Translating These Findings into Educational Practice

The findings reviewed and literature cited in this chapter show that spatial ability is linked to later STEM achievement and that as a whole spatially talented students and adults are being neglected (Lubinski 2010; Wai et al. 2009a). In addition, given that spatial ability is correlated lower with socioeconomic status in comparison to math and verbal abilities means that by using spatial ability measures we can capture more talented students from lower income backgrounds (Austin and Hanisch 1990; Wai and Worrell 2016). This can also help a population that may not have the support that other more fortunate students possess (e.g. parents that can help provide opportunities for spatial development that the traditional school system doesn't provide) (Wai and Worrell 2016). So what can we do to help translate what we know into educational practice?

Spatially talented students may be frustrated by how schools primarily emphasize the symbol systems of words and numbers (Gohm et al. 1998) and really the ability to speak, read, write, and do math (Wai 2011, 2013). Because some findings suggest that working in a "hands on" manner is important to this special population, for chemistry or physics classes one strategy might be to increase the time in the laboratory. Or when learning organic chemistry, students could be encouraged to create molecules in three dimensions during class using the standard kits. Robotics or architectural design courses might be introduced to encourage future engineers. Another research area suggests that reasoning with figures and shapes might help the spatially gifted learn subject matter. Thus when teaching a topic such as multivariate statistics to the gifted, the matrix algebra or geometric method might be used instead of traditional algebraic ones (Wai et al. 2009b). And even basic math could be taught in a primarily visual manner (Wai 2013). And to help spatially talented students increase their interest in reading, perhaps they might read biographies of famous spatially oriented and hands on scientists such as Thomas Edison (West 1991) or a current entrepreneur-engineer like Elon Musk (Vance 2015). The "maker movement" which encourages hands on projects and also things like FIRST robotics league may also be extracurricular activities that spatially oriented students might find helpful. In general, however, the key will be to find ways to increase both the spatial educational dosage for students (Wai et al. 2010) as well as look to factors such as teachers, administrators, parents, or really the larger educational culture not valuing students with spatial strengths and not understanding how creative they can be (Wai and Worrell 2016).

6.9 Broader Societal Implications: What Innovations Have We Already Lost?

In July 2015 NASA's mission to Pluto became a success (Gebelhoff 2015; New Horizons 2015), and the scientific community was ecstatic. But what many don't realize is that the project was to a large degree an endeavor that required incredible engineering and spatial ingenuity in addition to programming and other talents. In other words, spatially talented people played a large role. But just as the employees who make it through the talent filter for one of Elon Musk's companies (Vance 2015; Wai 2015a), the NASA engineers who were a part of that project were likely dominated by people who had the opportunity to develop their spatial talent well into adulthood. There are many spatially talented kids (especially from low income backgrounds) who may not have similar support, and it is this neglected population, and the corresponding innovations that they might have already created for all of us (but did not have the chance to), that we should think about (Wai and Worrell 2016). When Peter Thiel pointed out that flying cars was the goal but instead we got Twitter, he made the point that innovation is not nearly where it could be. He argued that by focusing on things like apps on our smartphones, perhaps even one as widely used and arguably innovative as Twitter, is simply thinking too small. Indeed, despite the current era often being touted as one characterized by intense creativity, there is evidence the rate of major innovations is actually on the decline (Cowen 2011; Huebner 2005). Thiel's concern led him to create his Thiel Fellows program – which identifies talented young entrepreneurial minded kids (some of them spatially talented) – to jumpstart innovation for society. The research is quite clear that spatial ability is important for STEM and innovation and for our future. But because we have neglected this incredibly talented population, we may have already lost so many innovations, whether they come from Nobel Prize winners like Shockley and Alvarez, NASA's mission team to Pluto, or from engineering entrepreneurs such as Elon Musk. How many of these kids have we already let fall through the cracks? Perhaps it's time to focus on helping spatially talented students engineer our future so that we might have incredible things that are not yet imagined.

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