# International Differences in Mathematical Achievement: Their Nature, Causes, and Consequences

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Every now and then, a spate of popular-press articles reminds us of the poor educational achievement of American children in comparison to their international peers. For many people, concerns about the education of American children likely fade, as these articles are bumped from our memory by a slew of hotter popular-press issues. In this article, the mathematical achievement of American children is first contrasted with that of their cohorts in other industrialized nations, and then sources of these cross-national achievement differences are briefly reviewed. The article closes with a discussion of the potential consequences of the poor mathematical development of American children, consequences that speak to the importance of the associated educational issues and remind us that our concern for the education of American children must continue unabated, even after the popular press has moved on to other issues.

## NATURE

In 1964, the International Project for the Evaluation of Educational Achievement (IEA) conducted the first large-scale multinational study of mathematical achievement (Husén, 1967). The results of this study, which included 13- and 17-year-olds from 12 industrialized nations, were the first to systematically document the poor mathematical development of American adolescents relative to their international peers.[2] The overall performance of the American 13-year-olds ranked 11th, and their mean scores were below the international mean in every area assessed (i.e., arithmetic, algebra, and geometry). The American 17-year-olds fared worse. The overall mean performance of these largely college-bound seniors was considerably below the international mean (by about 1 standard deviation) and was considerably lower than the mean performance of adolescents from the 11th-ranked nation.[3] In other words, these American seniors not only ranked last overall, but about 4 out of 5 of them scored below the international average.

The second IEA study, conducted in the early 1980s, and more recent assessments have also yielded alarming results (Crosswhite, Dossey, Swafford, McKnight, & Cooney, 1985; Lapointe, Mead, & Askew, 1992). For instance, the second IEA study included a comparison of 17-year-olds enrolled in college-prep math courses (about 13% of American high school seniors) from 22 educational systems. The top 5% of these elite American students had only average scores in relation to the international standard in algebra and in functions and calculus, and had slightly above average scores in geometry (M.D. Miller & Linn, 1989). This same comparison showed that within this relatively elite group, students who scored at the 95th percentile in the United States would score at about the 30th percentile in Japan and the 50th percentile in England. America's most elite students, the top 1 %, consistently scored below the most elite students from most other nations. The gap was especially large for geometry. For instance, fewer than 1 out of 5 and only 1 out of 10 of America's most elite geometry students scored above the average college-prep Hungarian and Japanese student, respectively.

The research of Stevenson, his colleagues, and other investigators has also revealed important differences in the mathematical development of American children and children from East Asian nations, specifically, China, Korea, Japan, and Taiwan (Geary, Fan, & Bow-Thomas, 1992; Song & Ginsburg, 1987; Stevenson, Chen, & Lee, 1993). Differences in the mathematical achievement of American children and East Asian children are consistently found in first grade (sometimes in kindergarten), are evident for nearly every area of mathematical competence that is taught in school, and become greater with each successive year of schooling. Stevenson et al. (1993) found that the top 10% of American 5th and 11th graders had mathematics test scores that were at about the average of Japanese and Taiwanese children of the same age. Moreover, the gap might become even wider in the future, as the mathematical competencies of children from some East Asian nations (e.g., Taiwan) are improving from one genera-

**Recommended Reading**

Geary, D.C. (1994). (See References)
Stevenson, H.W., Chen, C., & Lee, S.Y. (1993). See References)
Stevenson, H.W., Stigler, J.W. (1992). (See References)

tion to the next (Stevenson et al., 1993), while the competencies of American students are static or declining (Geary, Salthouse, Chen, & Fan, 1996).

The results of these studies are clear: American children do not measure up to international standards in mathematical achievement---and have not for many decades. The following sections present an overview of potential causes of the achievement gap between American children and their East Asian and European peers. The focus is primarily on American and East Asian children because the differences between them have been studied more systematically than have the differences between American and European children. Overall, the causes of the gap between American children and European children and between American children and East Asian children are likely similar in many respects (e.g., differences in mathematics curricula) but differ in others (e.g., language differences, described later).

## CAUSES

In considering potential causes of cross-national differences in mathematical achievement, it is useful to distinguish between biologically primary and biologically secondary abilities (Geary, 1995). The former are natural abilities that have been shaped by evolutionary processes, whereas the latter are, in a sense, unnatural. Language is an example of a natural, or primary, ability that is found in one form or another throughout the world. Reading is an example of an unnatural, or secondary, ability because learning to read involves the use of language, and other primary systems, in unnatural ways.[4] Language and other primary abilities emerge largely in the context of children's natural activities, such as play. Reading and other secondary abilities emerge largely in unnatural contexts, primarily school. Moreover, the motivation to acquire primary abilities is likely to be inherent, whereas the motivation to acquire secondary abilities is more strongly influenced by cultural goals than by the inherent interests of children.

A distinction between primary and secondary mathematical domains has important implications for understanding potential biological as well as cultural influences on cross-national differences in mathematical achievement (Geary, 1995).[5] If the source of cross-national differences in mathematical development is largely biological, then these differences should be evident in primary domains and before the onset of formal schooling. If differences in mathematical achievement are largely the result of cultural influences, then these differences should be evident for secondary, but not primary, domains, and the source of the differences should stem largely from schooling and the cultural valuation of mathematical achievement.

### Biology and Intelligence

Although the definitive study has yet to be conducted, it does not appear that East Asian and American children differ in primary mathematical abilities, suggesting that it is very unlikely that there is anything like an "Asian math gene" (Song & Ginsburg, 1987). In other words, except for the influence of language on the development of early counting skills (described next), East Asian children do not start school with an advantage over their American peers in fundamental mathematical competencies (K.F. Miller, Smith, Zhu,& Zhang, 1995).

Similarly, it does not appear that potential racial differences in the intelligence (IQ) of American and East Asian children can explain the achievement gap. Although Lynn (1982, 1983) estimated that there was about a 4-point difference in the mean IQs of Japanese and American children, Stevenson and his colleagues (1985) found no evidence for mean IQ differences across groups of Anglo-American, Japanese, and Chinese children. Thus, if the mean IQs of East Asian children are higher than those of Anglo-American children, the differences are likely to be rather small and not sufficient to explain the large cross-national differences in mathematical achievement. Of course, any racial differences in IQ cannot explain the mathematical achievement gap between Anglo-American children and children from most European countries.

### Language

In East Asian languages, number words past 10 are translated as "ten one," "ten two," "ten three" (i.e., 11, 12, 13), . . ."two ten one," "two ten two," "two ten three" (i.e., 21, 22, 23), and so on. These number words mirror the underlying base-10 structure of the number system. In European languages, including English, there is no straightforward correspondence between number words from 11 to 100 and the underlying base-10 system. For most American children, "thirteen," for instance, represents a collection of 13 items, not one 10 and three 1s. For East Asian children, it is obvious that the corresponding number word "ten three," represents one 10 and three 1s.

Because of this difference in the structure of number words, East Asian children make fewer counting errors (past 10) and understand some counting, number, and basic arithmetic concepts, such as place value, at a younger age than both their American and their European peers (Miura, Okamoto, Kim, Steere, & Fayol, 1993; K.F. Miller et al, 1995). Nevertheless, the influence of the structure of number words on mathematical competencies is probably limited to certain counting and arithmetical abilities and is not sufficient to explain the more ubiquitous achievement gap between American and East Asian children, or the gap between American children and children from most European countries.

**Schooling**

Relative to international standards, the mathematics curricula in most American school districts is poorly organized and too easy. For instance, it has been found that many arithmetic topics that are introduced in the fifth or sixth grade in the United States are introduced in the second or third grade in Japan, China, the former Soviet Union, and Taiwan (e.g., Fuson, Stigler, & Bartsch, 1988). Even when the same topics are taught, the materials tend to be more conceptually advanced in many European and East Asian mathematics curricula than in the mathematics curricula in most U.S. school districts.

In comparison to American children, children in East Asian and most European nations do more mathematics homework and receive more mathematics instructtion in school; they are on task more often during math lessons and have more math lessons during the school year (Lapointe et al, 1992; Stevenson et al, 1993; Stevenson & Stigler, 1992). The nature of math lessons differs as well (Perry, VanderStoep, & Yu, 1993; Stevenson & Stigler, 1992). For instance, East Asian children spend the majority (74% to 90%) of their math instruction time engaged in activities directed by the teacher, such as discussing a particular problem. American children, in contrast, spend about one half of their time doing seat work or other activities (e.g., socializing) that are not directed by the teacher. On average, mathematics teachers in East Asia tend to foster children's conceptual understanding of the material better than American teachers. For example, East Asian teachers are much more likely than American teachers to ask children to come up with as many different ways as possible to solve the same problem, a method that fosters the conceptual understanding of the problem (Geary, 1994).

**Cultural Valuation**

Except for the influence of the structure of number words on early counting skills, the first emergence of differences in mathematical achievement between East Asian and American children occurs with the onset of formal schooling and occurs largely for unnatural, or secondary, mathematical domains. This pattern strongly implicates schooling as the primary source of cross-national differences in mathematical achievement (see also Husén, 1967). Differences in the mathematical schooling of East Asian and American children, in turn, reflect deeper and more pervasive cultural differences in the valuation of mathematical achievement (Stevenson & Stigler, 1992). Hatano (1990) suggested that differ-ent nations not only develop and emphasize different national sports, they also develop different cognitive-educational emphases. Mathematics is an area of emphasis in East Asia, but is deemphasized in the United States. These cultural differences in the importance of mathematical competencies directly affect the in-school experiences of American and East Asian children. In China, for instance, elementary school mathematics teachers are specialists, teaching only mathematics, much as art teachers are specialists in the United States.

Another cultural factor that almost certainly influences mathematical achievement is the structuring of educational opportunities from one level of schooling to the next (e.g., primary to secondary). Relative to the United States, East Asian nations, and many European nations to a lesser extent, maintain a much stronger relationship between early educational accomplishments and later educational and employment opportunities. In many of these nations, excellent early academic achievement creates opportunities for advanced education (e.g., college) and subsequent improvements in standard of living through better employment. In contrast, America is the land of second chances, based on the belief that an individual's options for success should more or less always be available. There are certainly benefits to this cultural belief, but there are also costs. The most prominent of these costs is the ease with which achievement in primary and to a lesser extent secondary school can be deemphasized, without risking the opportunity to attend college.

When considered in terms of primary and secondary mathematical abilities, the importance of these cultural differences in the value of mathematics becomes clear: Cultural valuation of unnatural, or secondary, abilities is likely to be essential for high levels of development, given that most children, American, East Asian, and European, would prefer to do things other than learn secondary skills. American children are allowed to pursue their inherent interests much more than are East Asian and many European children, reflecting widely accepted cultural beliefs about the importance of "free choice." These cultural values, combined with the structure of educational opportu--ities, appear to influence children's exposure to mathematics in school and at home and, as a result, might be the ultimate source of differences in mathematical achievement between American children and children in most other industrialized nations.

## CONSEQUENCES

The gap in mathematical achievement between American children and children from East Asian and most European nations highlights lost educational opportunities within this country. Consider the comments of a noted economist: "When the academic achievement of students completing their schooling declines substantially, then economic costs are large and last for generations" (Bishop, 1989, p. 194). For instance, the sharp decline in the literacy and numeracy of American high school graduates from 1967 to 1980 was estimated to cost the U.S. economy $86 billion in 1986. The estimated costs would be considerably higher if international standards were used to gauge the adequacy of academic achievement in the United States.

Even basic arithmetic skills, specifically, the ability to do computations (e.g., 34 + 69) and to use arithmetic to solve "real-world problems" (i.e., word problems), are important. These basic quantitative skills have been found to influence employability, wages, and productivity in the United States as well as in other nations, above and beyond the influence of literacy, years of schooling, and intelligence (e.g., Rivera-Batiz, 1992). Thus, although the national differences summarized in this article might raise concerns about this country's ability to adequately educate enough individuals adequately for entry into math intensive careers (e.g., engineering), perhaps the real concern should be for the rest of us and our children.

## SUMMARY AND CONCLUSION

Thirty years of comparative assessments indicate that American children are consistently among the most poorly educated mathematics students in the industrialized world. The differences in the mathematical achievement of American children and their European and East Asian cohorts are evident as early as first grade, widen with successive years of schooling, and are substantial in magnitude. The finding that East Asian and American children do not differ in more primary, or natural, mathematical abilities indicates that East Asian children do not begin school with an advantage over their American peers and that it is very unlikely that the source of the mathematical achievement gap is primarily biological in origin. In fact, except for the influence of number words on certain counting and arithmetic skills, these differences emerge with the onset of formal schooling and are found largely for secondary mathematical domains, those domains most strongly influenced by schooling (Geary, 1995).

Indeed, important differences in the quantity and quality of the mathematics education of American children relative to East Asian and European children point to schooling as the primary source of cross-national differences in mathematical achievement. These schooling differences, in turn, reflect more pervasive cultural differences in the valuation of mathematical achievement and the relative importance of primary and secondary schooling for later educational and thus employment opportunities. The poor mathematiccal competence of American children is cause for serious national and, for those of us with children in the public schools, personal concern, as this poor competence bodes long-term social and economic consequences for the United States.

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**Notes**

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2. The participating nations were Australia, Belgium, England, Finland, France, Germany, Holland, Israel, Japan, Scotland, Sweden, and the United States.

3. Adolescents from Belgium, Ger-many, Israel, and Japan consistently scored above the international mean in nearly all mathematical areas.

4. For example, the phonological (i.e., language sound) system that supports language was not designed for reading, but with instruction can be used for this purpose (specifically, for sounding out words).

5. Primary mathematical abilities include, among others, the ability to distinguish sets of small numbers of items without counting (e.g., sets of three vs. four objects), an understanding that adding increases quantity and subtraction decreases quantity (again, for small numbers), and some basic counting skills. Much of mathematics, however, is biologically secondary. Secondary mathematical abilities in-

clude, among others, learning number names (e.g., "one," "two," "three"), complex arithmetic (e.g., 34 + 46 = ?), and most features of more complex mathematical domains (e.g., algebra).

## References


Bishop, J.H. (1989). Is the test score decline responsible for the productivity growth decline? *American Economic Review, 79*, 178-197.

Crosswhite, F.J., Dossey, J.A., Swafford, J.O., McKnight, C.C., & Cooney, T.J. (1985). *Second International Mathematics Study summary report for the United States.* Champaign, IL: Stipes.

Fuson, K.C., Stigler, J.W., & Bartsch, K. (1988). Grade placement of addition and subtraction topics in Japan, Mainland China, the Soviet Union, Taiwan, and the United States. *Journal for Research in Mathematics Education, 19*, 449-456.

Geary, D.C. (1994). *Children's mathematical development: Research and practical applications.* Washington, DC: American Psychological Association.

Geary, D.C. (1995). Reflections of evolution and culture in children's cognition: Implications for mathematical development and instruction. *American Psychologist, 50*, 24--37.

Geary, D.C., Fan, L., & Bow-Thomas, C.C. (1992). Numerical cognition: Loci of ability differences comparing children from China and the United States. *Psychological Science, 3*, 180-185.

Geary, D.C., Salthouse, T.A., Chen, G.-P., & Fan, L. (1996). Are East Asian versus American differences in arithmetical ability a recent phenomenon? *Developmental Psychology, 32*, 254--262.

Hatano, G. (1990). Toward the cultural psychology of mathematical cognition. Commentary on Stevenson, H.W., Lee, S.-Y., Chen, C., Stigler, J.W., Hsu, C.C., & Kitamura, S. Context of achievement: A study of American, Chinese, and Japanese children. *Monographs of the Society for Research in Child Development, 55* (1-2, Serial No. 221).

Husén, T. (1967). *International study of achievement in mathematics: A comparison of twelve countries* (Vols. 1 and 2). New York: Wiley.

Lapointe, A.E., Mead, N.A., & Askew, J.M. (1992). *Learning mathematics*. Princeton, NJ: Educational Testing Service.

Lynn, R. (1982). IQ in Japan and the United States shows a growing disparity. *Nature, 297*, 222-223.

Lynn, R. (1983). Reply to Stevenson and Azuma. *Nature, 306*, 292.

Miller, K.F., Smith, c.M., Zhu, J., & Zhang, H. (1995). Preschool origins of cross-national differences in mathematical competence: The role of number-naming systems. *Psychological Science, 6*, 56--60.

Miller, M.D., & Linn, R.L. (1989). Cross-national achievement with differential retention rates. *Journal for Research in Mathematics Education, 20*, 28-40.

Miura, I.T., Okamoto, Y., Kim, C.C., Steere, M., & Fayol, M. (1993). First graders' cognitive representation of number and understanding of place value: Cross-national comparisons---France, Japan, Korea, Sweden, and the United States. *Journal of Educational Psychology, 85*, 24--30.

Perry, M., VanderStoep, S.W., & Yu, S.L. (1993). Asking questions in first-grade mathematics classes: Potential influences on mathematical thought. *Journal of Educational Psychology, 85*, 31-40.

Rivera-Batiz, F.L. (1992). Quantitative literacy and the likelihood of employment among young adults in the United States. *Journal of Human Resources, 27*, 313--328.

Song, M.J., & Ginsburg, H.P. (1987). The development of informal and formal mathematical thinking in Korean and U.S. children. *Child Development, 58*, 1286-1296.

Stevenson, H.W., Chen, C., & Lee, S.Y. (1993). Mathematics achievement of Chinese, Japanese, and American children: Ten years later. *Science, 259*, 53--58.

Stevenson, H.W., & Stigler, J.W. (1992). *The learning gap: Why our schools are failing and what we can learn from Japanese and Chinese education.* New York: Summit Books.

Stevenson, H.W., Stigler, J.W., Lee, S.Y., Lucker, G.W., Kitamura, S., & Hsu, C.C. (1985). Cognitive performance and academic achievement of Japanese, Chinese, and American children. *Child Development, 56*, 718-734.