# The Two Cultures: A Zero-Sum Game?

Michael R. Scheessele, Assistant Professor, Indiana University South Bend

## Abstract

In *The two cultures and the scientific revolution*, C.P. Snow (1959) described the chasm between pure and applied science, on the one hand, and the arts and humanities, on the other. Snow was concerned that the complete lack of understanding between these "two cultures" would hamper the spread of the scientific/industrial revolution from rich nations to poor. Because of his conviction that this revolution had made lives longer and more comfortable for people of developed nations, he forcefully argued that the two intellectual cultures must be bridged – the sooner the better.

The gap between these two cultures, of course, still exists. Meanwhile, the arts are neglected in primary and secondary schools. Further, the science vocabulary of adults in the U.S. appears to be so poor that a scientific theory is considered suspect simply because it is "just a theory". Such problems may create increased competition between the two cultures. A probable result would be short-sighted prescriptive measures that are at best worthless and at worst dangerous to the mission of bridging the two cultures. A better approach may be to examine interdisciplinary fields where this gap seems less wide, for clues to a bridge.

## Introduction

In *The Two Cultures and the Scientific Revolution,*[1] C.P. Snow (1959) described the emergence of two broad, yet distinct, intellectual cultures in Western society. The first of these, embodied by the literary intellectual, encompasses the arts and humanities. The other, embodied by the scientist, comprises mathematics and technology, in addition to the natural and social sciences. Snow was disturbed by the deep lack of understanding and communication between members of these two cultures:

> Thirty years ago the cultures had long ceased to speak to each other: but at least they managed a kind of frozen smile across the gulf. Now the politeness has gone, and they just make faces.[2]

His conviction was that science and technology had made life longer and more bearable for those fortunate enough to have been born in industrialized nations and, further, that the scientific revolution could ease suffering for those living in poor nations. However, he believed that this gulf between the two cultures was hindering the spread of the scientific revolution from

[1] C.P. Snow, *The Two Cultures and the Scientific Revolution* (New York: Cambridge University Press, 1959).
[2] Ibid., 19.

developed to developing nations, in part because the resulting lack of more complete knowledge was acting to constrain the judgment of policy-makers.[3] Thus, Snow proposed more broad education for students with the hope that this gulf between the two cultures might begin to be bridged.

The basic problem of the two cultures persists however. Proposed U.S. funding increases for math and science will likely exacerbate tension between the two cultures, due to the perception that the arts and humanities – especially the arts – are already neglected when compared to the sciences. It would be tempting for the scientist to just sit back and enjoy the windfall, while the literary intellectual rails at the prospect of yet more money being diverted toward the sciences (presumably at the expense of the arts and humanities). Increased tension between the two cultures would be unfortunate though – at least in the U.S. At best it would achieve nothing; at worst it may distract attention from a critical question, is America in danger of losing its dominance in science and technology? If the answer is yes, then the problem will definitely be addressed. After all, no reasonably informed person today would dispute the role that science plays in a healthy, prosperous society. But what form should a solution take? Increased rivalry between the two cultures would likely obscure paths to an answer.

**U.S. Science And Technology In Peril?**

The United States has enjoyed dominance for decades in terms of scientific discovery and technical innovation. That America also has one of the highest standards of living in the world is no coincidence, and this echoes the assertion by Snow that:

> The scientific revolution is the only method by which most people can gain the primal things (years of life, freedom from hunger, survival for children) – the primal things which we take for granted and which have in reality come to us through having had our

[3] C.P. Snow, *The Two Cultures: And a Second Look* (Cambridge: Cambridge University Press, 1965), 60-61.

> own scientific revolution not so long ago. Most people want these primal things. Most people, wherever they are being given a chance, are rushing into the scientific revolution.[4]

Two recent high profile reports - one by the National Academies,[5] the other led by the Business Roundtable[6] - warn that American prowess in science and technology may be slipping relative to that of other nations and that unless immediate action is taken, American prosperity may be at stake. These warnings are hardly surprising though. Reports that American students lag behind their international counterparts in math and science have been related in the news for years. The never-ending debate on whether creationism/Intelligent Design should be taught alongside evolution in American science classrooms provides just one illustration of scientific illiteracy in American adults. For example, one reason sometimes given in support of teaching creationism/Intelligent Design as an alternative to evolution is that evolution is "just a theory".[7] Thus, "theory" is nearly transformed into a dirty word, in spite of the fact that much of scientific knowledge is just a theory. Having a more scientifically literate American public would not end this debate, but it would at least make it slightly less embarrassing. Where are the scientists in this debate? Beyond obligatory scientific courtroom testimony and the occasional op/ed column written by a scientist, why does one see so few attempts at explaining the difference between a theory and a law, as well as why laws can be so hard to come by in science? Further, if scientists could explain the limitations of science for non-scientists, it would remove the perception of

---

[4] Ibid., 79-80.
[5] National Academies Committee on Prospering in the Global Economy of the 21st Century: an Agenda for American Science and Technology, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future, Pre-Publication Version, February 2006 Edition* (Washington, DC: National Academies Press, 2006).
[6] Business Roundtable, *Tapping America's Potential: The Education for Innovation Initiative* (Washington, DC: Business Roundtable, 2005), http://www.businessroundtable.org//publications/index.aspx .
[7] Samir Okasha, *Philosophy of Science: a Very Short Introduction* (New York: Oxford University Press, 2002), 127-128.

threat to at least some conceptions of God and of faith. Are scientists fully aware of the limitations of science themselves? Scientific training includes learning about the scientific method and the objectivity of science, that a theory must be falsifiable, and that science is a search for the truth. However, aspects of each of these concepts are still debated by philosophers of science.[8] Perhaps ignorance of basic philosophy of science limits the ability of scientists to more fully engage non-scientists in controversial discussions.

An examination of whether U.S. science and technology is in decline requires more than such casual observations, however. First, the current state of mathematics and science education must be considered relative to that of other countries. Also, the current health of American science and technology must be assessed relative to that of other countries.

**U.S. Mathematics And Science Education**

Evaluating the current state of mathematics and science education in the United States requires assessment of the performance of American students in mathematics and science, particularly as compared to that of their counterparts in other countries. In the United States, three major assessments are used: the National Assessment of Educational Progress (NAEP), the Trends in International Mathematics and Science Study (TIMSS), and the Program for International Student Assessment (PISA). These three assessments may have different goals, sample from different populations of students, and employ different assumptions in design of the assessments themselves. Thus, caution must be used in comparing and contrasting results between the three assessments. For example, the NAEP, also known as the "Nation's Report Card", has as its goal the assessment of the knowledge and ability of U.S. students exclusively. The TIMSS and the PISA, on the other hand, provide assessment of the performance of U.S. students relative to their

[8] Helen E. Longino, *Science as Social Knowledge: Values and Objectivity in Scientific Inquiry* (Princeton, NJ: Princeton University Press, 1990); Okasha, *Philosophy of Science*.

counterparts in other countries. Whereas the NAEP assessment reflects the values and priorities of U.S. experts, the other two assessments were designed using international expertise. Even though the TIMSS and PISA are both international assessments, the sets of participating countries were not identical in the 2003 assessments. Further, in computing international performance averages, PISA factored in just the performance scores from the Organization for Economic Cooperation and Development (OECD) nations. TIMSS computed international performance averages using the performance scores from all participating nations, industrialized or not. While the NAEP and TIMSS sample student populations based on grade-level (NAEP samples 4th, 8th, and 12th grade populations; TIMSS samples 4th and 8th grade populations), PISA specifically samples 15-year olds (i.e., it samples based on age). In addition, PISA was designed to measure the "yield" of student learning by an age where students in many countries wind down their mandatory studies. NAEP and TIMSS, on the other hand, are curriculum-based assessments. These and other differences between the three assessments necessitate cautious inter-assessment comparison, but, collectively, the three assessments may give a more complete perspective on the state of U.S. mathematics and science education.[9] Given this brief background, recent results of each assessment are now considered.

The National Assessment of Educational Progress (NAEP) showed that both 4th and 8th grade mathematics knowledge and ability steadily improved from 1990 to 2003.[10] The 2005 NAEP mathematics assessment showed slight gains for 4th and 8th grade students, as compared to the 2003 assessment. The percentage of students performing in mathematics at least at a

[9] U.S. Department of Education, National Center for Education Statistics, *Comparing NAEP, TIMSS, and PISA in Mathematics and Science* (Washington, DC: U.S. Department of Education, National Center for Education Statistics, 2004), http://nces.ed.gov/timss/pdf/naep_timss_pisa_comp.pdf .

[10] U.S. Department of Education, National Center for Education Statistics, *The Condition of Education 2005* (Washington, DC: U.S. Department of Education, National Center for Education Statistics, U.S. Government Printing Office, 2005), Indicator 10.

"Proficient" level in 2005 was 36% for $4^{th}$ grade students and 30% for $8^{th}$ grade students.[11] For $12^{th}$ grade students, mathematics performance was higher in 2000 than in 1990, despite a decline in performance between 1996 and 2000. The percentage of $12^{th}$ grade students in 2000 performing in mathematics at least at a "Proficient" level – defined as "the level that all students should reach"[12] – was 17%.[13] With respect to science, the 2000 NAEP science assessment of $4^{th}$, $8^{th}$, and $12^{th}$ grade students showed no significant improvement in average science scores for $4^{th}$ and $8^{th}$ grade students between 1996 and 2000; the $12^{th}$ grade average science score declined from 1996 to 2000. The percentage of students in 2000 performing in science at least at a "Proficient" level – defined as "the level that all students should reach" – was 29% for $4^{th}$ grade students, 32% for $8^{th}$ grade students, and 18% for $12^{th}$ grade students.[14] In the 2005 NAEP science assessment of $4^{th}$, $8^{th}$, and $12^{th}$ grade students, $4^{th}$ grade performance was significantly higher than in 2000, while $8^{th}$ and $12^{th}$ grade performance did not significantly change from 2000. The percentage of students performing in science at least at a "Proficient" level in 2005 was 29% for $4^{th}$ grade students, 29% for $8^{th}$ grade students, and 18% for $12^{th}$ grade students.[15]

The 2003 TIMSS assessment showed that mathematics performance of U.S. $4^{th}$ grade students remained unchanged, while that of U.S. $8^{th}$ grade students improved, between 1995 and 2003. Overall, this assessment reported $4^{th}$ grade mathematics performance for 25 countries and $8^{th}$ grade mathematics performance for 45 countries. Both U.S. $4^{th}$ and $8^{th}$ grade mathematics

[11] Marianne Perie, Wendy S. Grigg, and Gloria S. Dion, *The Nation's Report Card: Mathematics 2005* (Washington, DC: U.S. Department of Education, National Center for Education Statistics, 2006), http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2006453 .

[12] J.S. Braswell, A.D. Lutkus, W.S. Grigg, S.L. Santapau, B.S.-H. Tay-Lim, and M.S. Johnson, *The Nation's Report Card: Mathematics 2000* (Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement, National Center for Education Statistics, 2001).

[13] Results from the 2005 NAEP mathematics assessment for $12^{th}$ grade students reportedly will be released in summer 2006.

[14] C.Y. O'Sullivan, M.A. Lauko, W.S. Grigg, J. Qian, and J. Zhang, *The Nation's Report Card: Science 2000* (Washington, DC: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, 2003).

[15] W. Grigg, M. Lauko, and D. Brockway, *The Nation's Report Card: Science 2005* (Washington, DC: U.S. Department of Education, National Center for Education Statistics, U.S. Government Printing Office, 2006).

performance was higher than the international average in 2003. Assessment results show, however, that U.S. 4th grade students lost ground in mathematics when considering only the 15 countries that took part in both the 1995 and 2003 TIMSS assessments. In 1995 four of these countries performed significantly higher than the U.S., while in 2003 seven of these countries performed significantly higher than the U.S. Meanwhile, U.S. 8th grade students appeared to gain ground in mathematics between 1995 and 2003, when considering only the 23 countries that took part in both assessments. In 1995 twelve of these countries performed significantly higher than the U.S., while in 2003 seven of these countries performed significantly higher than the U.S. The 2003 TIMSS assessment showed a nearly identical pattern for science: unchanged performance for U.S. 4th grade students between 1995 and 2003, improved performance for U.S. 8th grade students over this time period, scores above the international average in 2003 for both U.S. 4th and 8th grade students, lost ground for U.S. 4th graders and gained ground for U.S. 8th graders when considering just the countries for each grade level that participated in both assessments (U.S. Department of Education, National Center for Education Statistics 2005).[16]

For the other international assessment, the PISA, the goal is to measure the "yield" of education as of age 15. This age is used because it is close to where mandatory schooling ends for students in many countries. The PISA has more of a mathematics and science "literacy" focus than either the NAEP or TIMSS, using a higher percentage of open-ended as opposed to multiple choice mathematics questions than either of these assessments, for example.[17] The 2003 PISA included 29 industrialized Organization for Economic Cooperation and Development (OECD) countries and 11 non-OECD countries. Only the scores from the industrialized OECD countries

---

[16] U.S. Department of Education, National Center for Education Statistics, *The Condition of Education 2005,* Indicators 11-12.
[17] U.S. Department of Education, National Center for Education Statistics, *Comparing NAEP, TIMSS, and PISA in Mathematics and Science*.

were used in computing international average scores. U.S. 15-year olds scored significantly lower than the international average in mathematical literacy and problem solving.[18]

With respect to elementary school mathematics education, a reasonable interpretation of these varied findings seems to be that progress is being made though much work is still needed, as evidenced by the low percentages of 4th and 8th grade students performing at or above a level of proficiency deemed desirable for all students by U.S. experts. With respect to elementary school science education, the situation is similar, though somewhat more negative. As with mathematics, there are low percentages of 4th and 8th grade students performing at least proficiently, but the lack of improvement for 8th grade students found by NAEP between 1996 and 2005 is also discouraging. It is more difficult to judge U.S. elementary school mathematics and science education against that of other countries. The TIMSS report that U.S. 4th and 8th grade students performed higher than the international average in both mathematics and science in 2003 is very encouraging. However, the international average scores incorporated results from all participating countries - both industrialized and developing. The further TIMSS finding, that U.S. 4th grade student ranking slipped between 1995 and 2003 in both mathematics and science, while that of U.S. 8th grade students improved in both areas, is hard to judge because just 60% of the countries that participated in the 2003 TIMSS assessment of 4th grade students and just over half of the countries that participated in the 2003 TIMSS assessment of 8th grade students also participated in the 1995 assessments.

Both U.S. high school mathematics and science education seem to be broken. The NAEP results show not only a decrease in both mathematics and science performance for 12th grade students between 1996 and 2000 (math performance in 2005 has not yet been reported; science

---

[18] U.S. Department of Education, National Center for Education Statistics, *The Condition of Education 2005*, Indicator 13.

performance did not change between 2000 and 2005), but also that less than 20% of 12th grade students had at least proficient performance in either area. The 2003 PISA results (PISA results are included here because fifteen is the typical age of a U.S. high school sophomore), showing that U.S. 15-year olds lag behind their counterparts in industrialized nations in both mathematical literacy and problem solving, are especially discouraging. Because this assessment is designed to gauge the ability of 15-year olds to actually use their mathematics and science knowledge and skills in more 'real world' settings,[19] these results may speak more directly to the future health of scientific achievement and technological innovation in the U.S. relative to other countries. For example, perhaps the current perceived lack of interest in computing in the U.S. is confounded with a lack of adequate preparation.[20] Some prospective computer science students may simply find their initial fire for computing stamped out as they engage their first college computing courses armed with deficient mathematics and science literacy.

Based on similar assessment data, the National Academies report[21] and the Business Roundtable-led report[22] associated problematic K-12 mathematics and science education with the possible decline of American science and technology. The National Academies report suggested that student success in mathematics and science follows from student interest in these areas. It attributed a lack of sufficient student interest partly to the fact that many K-12 mathematics and science teachers do not have proper background in the subjects that they teach. Additionally, the report suggested that lack of student interest is reinforced by adults proud of

[19] U.S. Department of Education, National Center for Education Statistics, *Comparing NAEP, TIMSS, and PISA in Mathematics and Science*.
[20] National Academies, *Rising Above the Gathering Storm*, p. 3-31; Andrew J. Rotherham and Kevin Carey, "Expand the Pool of America's Future Scientists," *The Christian Science Monitor*, April 20, 2006, http://www.csmonitor.com/ (accessed April 20, 2006). Both of these sources make a similar point to mine.
[21] National Academies, *Rising Above the Gathering Storm*.
[22] Business Roundtable, *Tapping America's Potential*.

their own lack of mathematics competency.[23] To improve K-12 mathematics and science education, the following actions were recommended: recruit 10,000 new mathematics and science teachers each year using four-year scholarships as incentive, bolster mathematics and science training in 250,000 existing teachers using a variety of programs, and increase the "pipeline" of students able to pursue mathematics and science degrees by facilitating successful participation in advanced mathematics and science study in middle and high school.[24] The Business Roundtable report also recommended actions for improving the quality of K-12 mathematics and science teachers and for enabling middle school and high school students to pursue advanced mathematics and science study. Further, it proposed providing incentives so that colleges and universities will produce more mathematics and science graduates, as well as strengthen their mathematics and science teacher programs.[25]

In response to these high profile reports, the Bush administration has proposed, as part of the American Competitiveness Initiative, training 70,000 high school teachers to provide advanced mathematics and science instruction, enlisting 30,000 mathematics and science professionals to assist with improving high school mathematics and science instruction, and providing early support to students who fall behind in mathematics and science.[26] Whether these measures constitute an appropriate solution is currently under debate. Meanwhile, the National Academies report has warned that:

> The danger exists that Americans may not know enough about science, technology, or mathematics to significantly contribute to, or fully benefit from, the knowledge-based society that is already taking shape around us. Moreover, most of us do not have enough

[23] National Academies, *Rising Above the Gathering Storm*, p. 3-27.
[24] National Academies, *Rising Above the Gathering Storm*, ES-3-ES-4.
[25] Business Roundtable, *Tapping America's Potential*, 11-12.
[26] George W. Bush, *State of the Union Address*, January 31, 2006, http://www.whitehouse.gov/stateoftheunion/2006/print/index.html (accessed March 12, 2006).

> understanding of the importance of those skills to encourage our children to study those subjects—both for their career opportunities and for their general benefit. Other nations have learned from our history, however, and they are boosting their investments in science and engineering education because doing so pays immense economic and social dividends.[27]

Although the presence of a problem with U.S. mathematics and science education seems undeniable and has been recognized by academic, business, and government leaders, many parents – and their children – seem unaware that a problem exists. Johnson et al. reported that 57% of parents feel that their child's mathematics and science education is "fine as is", with 70% of parents of high school students "who think their child's school is teaching the right amount of math and science". Further, they reported that only 50% of students think that "understanding sciences and having strong math skills" is necessary for their future and only 41% think that "having great skills with computers and technology" is vital. Additionally, 45% agreed that they would "be really unhappy" if they "ended up in a job or career that required doing a lot of math or science".[28]

**U.S. Science And Technology**

Is American dominance in scientific discovery and technical innovation in danger? In addition to the issue of U.S. mathematics and science education just considered, many other issues must be weighed in order to answer this question. The previously mentioned National Academies study extensively evaluated numerous aspects of this question and concluded that the U.S. may be slipping as other nations gain strength in science and technology. It has proposed a number of

---

[27] National Academies, *Rising Above the Gathering Storm*, p. 3-24.
[28] Jean Johnson, Ana Maria Arumi, Amber Ott, and Michael Hamill Remaley, *Reality Check 2006: Are Parents and Students Ready for More Math and Science?* (Public Agenda, Education Insights, 2006), http://www.publicagenda.org/research/pdfs/rc0601.pdf .

specific measures to assist U.S. policy-makers in heading off this perceived challenge to American science and technology.[29] The Business Roundtable-led study has similarly warned that American science and technology is in peril and it has also proposed corrective measures.[30] Government efforts have joined with those of academia and business to draw attention to and halt the perceived decline of American science and technology. The National Academies report was initiated, for example, by the bipartisan prompting of U.S. Senators Lamar Alexander and Jeff Bingaman, as well as that of U.S. Representatives Sherwood Boehlert and Bart Gordon from the House Committee on Science.[31] Since the report, Boehlert has aggressively pushed Congress to adequately fund U.S. science and technology, particularly aspects of the Bush Administration's American Competitiveness Initiative.[32] This initiative requires $5.9 billion for fiscal year 2007 and approximately $136 billion over 10 years to fund research and development, facilitate innovation, and improve mathematics and science education.[33]

It seems prudent that an immediate start be made toward reinforcing American science and technology. Some reports seem overstated, however, especially those commenting on U.S. technology and, in particular, U.S. computer science and information technology. Two examples will be given here. First, in the influential *Communications of the ACM*, Glass posed the question, "Is the Asian Tiger preparing to take over the IT world?"[34] Now, this is a reasonable question. He gave several indicators of the emerging power of Asia (including China, India, and South Korea) in computing and information technology relative to the U.S. One indicator given was the report of a 60% decline in interest from 2000-2004 among U.S. college freshmen in

---

[29] National Academies, *Rising Above the Gathering Storm*.
[30] Business Roundtable, *Tapping America's Potential*.
[31] National Academies, *Rising Above the Gathering Storm*, viii.
[32] Spencer Chin, "Rep. Boehlert Urges Full U.S. Science Funding", *EETimes Online*, April 6, 2006, http://www.eetimes.com/ (accessed April 7, 2006).
[33] Ibid.
[34] Robert L. Glass, "Is the Crouching Tiger a Threat?", *Communications of the ACM* 49, no. 3 (2006): 19-20.

pursuing a major in computer science.[35] This statistic was derived from a survey by the Higher Education Research Institute (HERI) at UCLA and reported earlier in an article that appeared in *Computing Research News*.[36] It is a misleading statistic though. Sure, computer science professors are well aware of the steep drop in enrollment in the past few years. One is sometimes even tempted to speculate that computer science departments may become modern-day ghost towns, with sleek equipment and rusted-out professors. However, closer examination of the HERI data given in the *Computing Research News* article shows that the years 1999 and 2000 were the peak of an upward trend that overlapped the technology boom period of the latter half of the 1990s.[37] During this technology boom, it is only a slight exaggeration to say that money was thrown at anyone who was even modestly technical, even novice and marginal workers. It is not surprising then that freshman interest in computer science was high in the Fall of 2000. The technical bust had barely begun by then. When compared to the period from 1986-1994, approximately corresponding to the years between the technical boom of the 1980s and that of the 1990s, the percentage of incoming freshmen in Fall 2004 who indicated a desire to pursue computer science as a major was only slightly lower.[38] Other HERI data reported in this article show that freshman interest in pursuing computer science, engineering, and other technical disciplines combined was consistently in the 10-15% range from 1986 to 2004.[39]

As a second example, results of a Duke University study suggest that warnings of an imminent American-Asian technology power shift may be overblown.[40] This study debunked

---

[35] Ibid.
[36] Jay Vegso, "Interest in CS as a Major Drops Among Incoming Freshmen", *Computing Research News* 17, no. 3 (2005): http://www.cra.org/CRN/articles/may05/vegso.html (accessed March 12, 2006).
[37] Ibid., fig. 1.
[38] Ibid.
[39] Ibid., fig. 2.
[40] Gary Gereffi, Vivek Wadhwa, Ben Rissing, Kiran Kalakuntla, Soomi Cheong, Qi Weng, and Nishanth Lingamneni, *Framing the Engineering Outsourcing Debate: Placing the United States on a Level Playing Field with China and India* (Duke University, Master of Engineering Management Program, 2005).

media reports on comparative 2004 engineering college graduation rates between the U.S., China, and India. These media reports listed the U.S. as producing 70,000 new engineers, as compared to 600,000 for China and 350,000 for India. However, the Duke study showed that these numbers do not provide an accurate picture – the Chinese and Indian figures included sub-baccalaureate degrees, for example. The Duke study showed that in 2004 the U.S. awarded 137,437 bachelors degrees in engineering, computer science, and information technology. Meanwhile, China and India awarded 351,537 and 112,000 bachelors degrees, respectively, in these disciplines. Further, when normalized by population, the Duke study showed that the U.S. awarded more bachelors degrees per million citizens in 2004 in these disciplines than either China or India. Even when the sum of bachelors and sub-baccalaureate degrees was considered, the U.S. awarded more degrees per million citizens in 2004 in these disciplines: in the U.S. 750 degrees were earned per million citizens, in China 500 degrees per million citizens, and in India 200 degrees per million citizens. The conclusion of the Duke study was that the U.S. is not in immediate danger of losing its edge in technology, although continued improvement in elementary and high school education is necessary and increased college enrollment in engineering disciplines is desirable.[41] Because the Duke study is less alarming than prior reports, such as that of the National Academies,[42] it has sparked debate on the extent to which the American lead in science and, especially, technology is in danger.[43] A comment by the dean of the Pratt School of Engineering at Duke University, Kristina M. Johnson, reflects a moderate view within the debate:

---

[41] Ibid.
[42] National Academies, *Rising Above the Gathering Storm*.
[43] Douglas B. Fuller, "The Fact Remains, U.S. Tech Leadership Must Be Reinforced", *San Jose Mercury News*, April 7, 2006, http://www.mercurynews.com/ (accessed April 7, 2006); Robert J. Samuelson, "A Phony Science Gap?", *Washington Post*, February 22, 2006, http://www.washingtonpost.com/ (accessed February 22, 2006).

> Is the sky falling? No, not yet. But if our most talented domestic students don't go into engineering, the rest of us will have to prop it up somehow.[44]

The two examples given here are not intended as evidence against claims that American science and technology are declining relative to the rest of the world. Nor are they intended as evidence that immediate action is unnecessary. Rather, the point here is that panic should be avoided in deciding how to correct the situation. Statistics that are given out of context or that are inaccurate may give rise to rushed and harmful prescriptive measures. Even the National Academies report stated that:

> By most available criteria, the United States is still the undisputed leader in the performance of basic and applied research... In addition, many international comparisons put the United States as a leader in applying research and innovation to improve economic performance.[45]

In exploring the health of American science and technology relative to that of other countries, much attention has been given to the practice of "offshoring" technical jobs to countries such as India and China. This phenomenon will now be briefly considered. The Job Migration Task Force of the Association for Computing Machinery (ACM) has produced a comprehensive report, *Globalization and Offshoring of Software*,[46] which examines the recent phenomena of the globalization of information technology (IT) and the offshoring of software and related services (e.g. project management, IT consulting), particularly from developed to developing nations. Though a unique aspect of this report is its deliberate focus on these phenomena from a truly global perspective (thereby reflecting the global nature of the ACM

---

[44] Kristina M. Johnson, "U.S. Engineers Hold Their Own", *Philadelphia Inquirer*, January 8, 2006, http://www.philly.com/ (accessed January 9, 2006).
[45] National Academies, *Rising Above the Gathering Storm*, p. 3-1.
[46] William Aspray, Frank Mayadas, and Moshe Y. Vardi, eds., *Globalization and Offshoring of Software (Summary and Overview Version)* (Association for Computing Machinery, ACM Job Migration Task Force, 2006).

membership), here the focus will be on aspects relevant to the question of relative decline in U.S. technology. First, a distinction should be made between "outsourcing" and "offshoring":

> *Outsourcing* refers to having work for a company done by another organization. *Offshoring* refers to having this work done in another country, whether or not it is done by part of the same company.[47]

According to this report, the globalization of IT has had a number of causes, including some obvious ones such as the global spread of inexpensive hardware and broadband. At any rate, the report implied that globalization of IT is here to stay and that offshoring is a "symptom"[48] of this globalization. While offshoring (along with the technical bust of the early 2000's) has been considered one cause of the dampened enthusiasm in the U.S. for studying computing in recent years, U.S. jobs lost have tended to be those involving more routine software and services work, according to the report. It claimed that an "upper limit" on vulnerable IT jobs may be approximately 12-14 million jobs over 15 years and that "to date, the annual job loss attributable to offshoring is approximately 2 to 3 percent of the IT workforce".[49] The report pointed out that this represents a small number when compared to total annual U.S. job loss and creation. In fact, the report was generally quite optimistic regarding the long-term U.S. need for domestic information technology workers. A stated reason for this optimism is the economic theory of comparative advantage:

> The economic theory of comparative advantage argues that if countries specialize in areas where they have a comparative advantage and they freely trade goods and services over the long run, all nations involved will gain greater wealth.[50]

[47] Ibid., 5.
[48] Ibid., 6.
[49] Ibid., 7.
[50] Ibid., 6.

For example, the U.S. is known for innovation. If an innovative U.S.-based company sends just the routine portions of its computer programming work to India, where salaries are lower, then the U.S. company would have more money to spend, presumably, on innovation. The assumption is that innovation gives rise to economic prosperity, and so, the U.S. as a whole would also benefit from this act of offshoring. India would benefit as well, because more of its programmers would be employed and because the Indian businesses supplying the programmers would also prosper.[51]

The ACM report acknowledged that this theory is not universally accepted, at least with respect to the globalization of information technology and offshoring. The report also recognized the pain felt by individuals and communities as jobs are shifted to a developing nation. Finally, it cautioned that developing nations such as India are actively trying to obtain higher-valued work, as opposed to more routine work, from developed nations. While there are some serious obstacles for India, such as the uneven quality of its higher education system, other factors work in its favor. One such factor is the return of Indian students that have studied and worked abroad, particularly in the U.S. Another factor is the practice of multinational corporations opening facilities in India. The report described how these and other factors may work to raise the level of innovation in information technology in developing countries such as India. In order to remain prosperous, the report prescribed that a developed nation, such as the U.S., should focus on its talent for innovation – which the Task Force seemed to regard as a catalyst for economic prosperity.[52] To foster continued technical innovation and creativity, the report suggested that

---

[51] Aspray et al., *Globalization and Offshoring of Software*.
[52] Ibid.

the computing curriculum in a developed nation may need to focus more on application areas and less on purely technical subject matter, for example.[53]

**Verdict?**

For purposes of determining whether U.S. science and technology may be losing ground to other nations, the foregoing analysis only scratches the surface. Yet, it seems two broad conclusions may be made. First, U.S. K-12 mathematics and science education must continue to improve, and the current push for more funding to enact this improvement is warranted. Mathematics and science education are obviously important to the future health of American science and technology, and therefore to the future health of the nation itself. Although the perceived lack of interest among college students in pursuing degrees in mathematics, science, and technology is no doubt a real phenomenon, it may also be symptomatic of inadequate K-12 mathematics and science preparation. Some students may be interested, but simply lack the preparation needed to make a start in these fields. The various academic, business, and government proposals to provide more well-trained K-12 mathematics and science teachers, and even to bring in outside mathematics and science professionals to assist, should provide students already interested in pursuing mathematics, science, or technology careers with the background needed for college study in these fields. Well-trained mathematics and science teachers may also attract students to these fields who were not initially interested in them. Second, given the critical role that science and technology plays in a healthy and prosperous society, it seems sensible to act as if American science and technology is in danger of slipping, even if the situation is not as dire as has been portrayed. In other words, there seems to be enough smoke to act as if there is a fire.

How then would increased attention and funding for science and technology affect the two cultures problem? Must it be done at the expense of the arts and humanities, thus driving the

[53] Ibid., 33.

two cultures further apart? Not if the attempt to solve the science and technology problem is handled wisely and free from panicky reaction. Spending more money to improve K-12 mathematics and science education may indeed take away opportunities for improving K-12 arts and humanities education. There are other aspects of the science and technology problem, however, where potential solutions seem consistent with the goal of bridging the two cultures. One example would be the ACM Job Migration Task Force prescription that a developed nation, such as the U.S., should continue to concentrate on innovation and creativity in information technology, because innovation is presumed to drive job creation and economic prosperity.[54] As mentioned above, this would involve incorporating more applications training into the computing curriculum. Many such application areas may simply be from other branches of science and technology, but other areas, such as graphic arts, may be from the arts and humanities. Further, the ACM report recommended that all nations, developed and developing, wanting to participate in the global IT field, should ensure that their computing students have the proper skills to interact in a global environment, including communication and teamwork skills, as well as knowledge of other languages and cultures.[55] In short, the globalization of IT, and other areas of technology, may offer opportunities for the two cultures to unite, in order to develop innovative, creative, globally-sensitive science and technology workers who fuel the economy with introduction of new technologies and applications.

Another example is that of interdisciplinary fields of study. Certain interdisciplinary fields currently seem able to span the two cultures and, if sufficiently supported, may also be well-positioned to generate future interest in science and technology. Similarly, many important problems cannot be completely solved by approaching from a single discipline. Such problems

[54] Aspray et al., *Globalization and Offshoring of Software*.
[55] Ibid., 33.

seem to require interdisciplinary solutions that may require collaboration between the two cultures.

**The Two Cultures: A Zero-Sum Game?**

As when Snow introduced it, the problem of the two cultures today interacts with the idea of science as catalyst for a healthy and prosperous society. Then, Snow's concern was that the two cultures problem would prevent the spread of the scientific revolution from developed to developing nations. Today, another concern is that the two cultures problem may needlessly distract from the pressing problem of how to retain the stature of U.S. science and technology, in order to maintain the health and prosperity of American society. By using the word 'needlessly', I do not wish to imply that the two cultures problem is today unimportant or irrelevant. Rather, it does not necessarily need to be framed as a problem in which one culture benefits at the other culture's expense. Sometimes this may seem to happen – as when yet more funding is proposed for K-12 mathematics and science education. However, the presence of interdisciplinary fields of study, for which the disciplines span the two cultures, shows that the two cultures can work together for mutual benefit. If policy-makers do not panic in response to the perceived decline of U.S. science and technology and if they have the courage to experiment a little, investment in such interdisciplinary areas of study may ease the problem of the two cultures and work toward sustaining U.S. scientific achievement and technical innovation as well. The idea that interdisciplinary fields of study may help bridge the gap between the two cultures is not new. Snow spoke of a "third culture", saying that "when it comes, some of the difficulties of communication will at last be softened…"[56] Snow's description of this "third culture" seems very similar to what today might be called an interdisciplinary field of study.[57] Likewise, the

---

[56] Snow, *The Two Cultures: And a Second Look*, 70-71.
[57] Ibid., 69-71.

idea of investing in an interdisciplinary field of study in order to support innovation is not new. As stated previously, the ACM Job Migration Task Force suggested that a computing curriculum in developed nations may do well to concentrate a little less on purely technical issues and a little more on applications in order to be innovative.[58] Further than this though, the report described the emergence of new kinds of computing and information technology training programs which could produce creative, innovative technologists:

> "…a variety of new academic units related to computing and information technology have begun to emerge in US universities. These include… campus-wide multidisciplinary information technology institutes aimed at fostering collaboration of faculty and students across departments. While they are not the programs intended to produce ace programmers or deep technical experts, the mix of skills and perspectives is a reasonable educational experiment to try to produce students well suited for higher-value-added jobs."[59]

While there are a number of interdisciplinary fields of study where disciplines span the two cultures, in this section two will be briefly examined: cognitive science and informatics (U.S.-style).

**Cognitive Science**

Cognitive science is the interdisciplinary study of the mind. It was established as a field around 1956 – some say specifically September 11, 1956, coinciding with the Symposium on Information Theory held at the Massachusetts Institute of Technology.[60] Disciplines which compose cognitive science are varied and include psychology, computer science (specifically

[58] Aspray et al., *Globalization and Offshoring of Software*, 33.
[59] Ibid., 30.
[60] Howard Gardner, *The Mind's New Science: A History of the Cognitive Revolution* (New York: BasicBooks, 1987), 28.

artificial intelligence), philosophy, neuroscience, linguistics, anthropology, and education. Cognitive science addresses certain questions originally posed long ago by philosophers. What is the relationship of mind to brain? What is the nature of consciousness? What is knowledge? How is it acquired and used? These are just a few of the questions pursued by cognitive scientists, and while answers are sought for their own sake, the knowledge obtained from such inquiry also informs fields such as education and design which clearly offer practical benefits.

What insights may be gleaned from cognitive science in order to foster better relations between the two cultures? I will give two examples here. The first insight is that cognitive science has existed for fifty years with the vigorous participation of disciplines from both cultures. True, in some of these disciplines only a fraction of the workers subscribe to the cognitive science agenda. Even so, the field of cognitive science serves as an existence proof that members from very different academic communities can publish in the same journals, attend the same meetings, and do so with minimal bloodshed. A partial explanation for this may be that many cognitive science research studies, while grounded firmly in one of the component disciplines, use techniques and knowledge from other disciplines as well. For instance, a vision researcher, intrigued by a philosopher's conjecture regarding some aspect of visual consciousness, may design both psychological and fMRI human experiments to test the conjecture. Assuming the collected data indeed provide evidence in favor of the philosopher's conjecture, the researcher may then team with a computer scientist to develop a computer model of the now fledgling theory of visual consciousness, in an attempt to corroborate the human data. This scenario is not unusual, and in fact, vision science seems to be a particularly integrated sub-field of cognitive science. Psychologists may use techniques pioneered in computer vision, in order to create stimuli for human experiments and to develop computer models of their theories.

Some computer vision researchers may employ the contributions of the Gestalt psychologists in order to build more effective machine vision systems, while others may try to faithfully simulate some neurophysiological aspect of the human vision system. Philosophers may debate whether human vision is computational or not. At a vision science meeting, one may even hear a talk on art with a vision-related theme. In other words, cognitive science and its sub-fields demonstrate that the two cultures can communicate and work together effectively. Such cooperation may occur because members of one academic discipline become familiar with the questions and open problems, as well as the techniques and knowledge, of some of the other disciplines that make up the field. They are then willing to incorporate the external information and skills into their own research when and where it may prove useful.

The second insight is perhaps a deeper version of the first and may be useful as a template for the study of *any* problem for which the solution may require input from multiple disciplines. Specifically, some aspects of cognitive science go so far as to make the component academic disciplines secondary to the object under investigation. This point is exemplified by the organization of an excellent introductory cognitive science textbook, *Mind: introduction to cognitive science, 2nd ed.*, by Paul Thagard.[61] In a typical organization for an introductory cognitive science textbook, one chapter would be devoted to each component academic discipline of cognitive science (e.g. psychology, philosophy, artificial intelligence, etc.). Thagard, on the other hand, took a different approach. He organized the text based on the field's mainstream premise that mental activity involves representations upon which computational operations are performed. This is the so-called Computational-Representational Understanding of Mind (CRUM). Rather than devoting chapters to the academic disciplines that compose cognitive science, Thagard devoted a chapter to each of the major mental representations (and

[61] Paul Thagard, *Mind: Introduction to Cognitive Science, 2nd edition* (Cambridge, MA: The MIT Press, 2005).

their corresponding mental computational operations) recognized by CRUM-adherents: logic, rules, concepts, analogies, images, and connections. In each chapter, he described and explained the contributions of the various academic disciplines which support or challenge the hypothesis of the mental representation explored in that chapter. This approach has the advantage of taking the focus off individual academic disciplines and placing it on the hypothesis of the mental representation itself. Thus, it may act to further break down barriers between academic disciplines. This approach may also permit connections between seemingly disparate research lines to be established, where otherwise they may not be. As an example, I had long been familiar with psychological research on the human ability to use analogies in problem solving, as well as aware of the idea of case-based systems in computer science. The connection between the two only became obvious after reading of their common support of analogy as a mental representation.[62] Although this is personal anecdote as opposed to hard evidence, creativity is believed to involve the ability to make associations between different knowledge domains.

While cognitive science may itself bring the two cultures closer together, as well as provide useful insights into bridging the two cultures, this is obviously not sufficient for increasing its funding. However, increased funding for cognitive science could assist with reversing the perceived decline of American science and technology. Since cognitive science is charged with discovering how we think, know, and learn, for example, results from cognitive science research could potentially inform and improve the teaching practices of K-12 mathematics and science teachers. Another application of cognitive science research is design, including design of intelligent user interfaces with technology. To the extent that such research facilitates the design and development of marketable, innovative technical products, it would fuel American technology.

[62] Ibid., ch. 5.

**Informatics**

Informatics is another interdisciplinary field, with some success at bridging the two cultures, where increased U.S. funding may also work toward bolstering American science and technology. Here, the U.S. interpretation of "informatics" is used (outside the U.S., "informatics" tends to be synonymous with "computer science"). At one of the pioneering institutions, Indiana University, an informatics student receives core training in computing and information technology combined with training in a "cognate" area of the student's choice. Cognate areas from which to choose span disciplines from the two cultures and include biology, business, chemistry, communication and culture, economics, fine arts, journalism, political science, psychology, and public and environmental affairs. Beyond simply training a student so that he or she may incorporate computing and information technology into the cognate discipline of his or her choice, the informatics program also encourages exploration of the interactions between technology and society, emphasizing ethical issues of technology use, for example.[63]

The design of a program such as informatics seems tailored for reducing barriers between the two cultures. Meanwhile, such a program is a prime example of the "reasonable educational experiment" described by the ACM Job Migration Task Force for producing innovative technology workers needed to create and fill higher-valued technology jobs.[64] Increased U.S. funding of informatics and similar programs would work toward solving the two cultures problem and may improve the health of U.S. science and technology as well. There are also subtle benefits to funding this type of program. For example, I have suggested that the current perceived lack of interest in computing as a major may be confounded with inadequate preparation for studying computing. Because a program such as informatics does not require the

[63] Indiana University, http://www.informatics.indiana.edu/ .
[64] Aspray et al., *Globalization and Offshoring of Software*, 30.

deep technical training that a computer science program would, it may be more accessible to students with some initial deficiencies in mathematics and science. For those students initially able to negotiate a major in computer science and having some interest in computing, but who are not enthusiastic about focusing exclusively on computing, substantial opportunity to apply computing skills in a separate cognate area may be appealing. In short, an interdisciplinary program with a substantial computing and information technology core may attract and retain students that a traditional computer science program would not. When coupled with more traditional computing programs, these newer programs could increase the total pool of U.S. technology workers, as well as the pool for the various cross-disciplinary positions requiring technology-savvy innovators.

**Two Final Points**

Before concluding this section, two points must be made. First, the two cultures problem and the perceived problem with U.S. science and technology will not be solved simply by funding interdisciplinary programs. Still, some of the money that will surely be spent in the next several years to bolster the position of U.S. science and technology should be directed toward interdisciplinary programs. As argued previously, these programs may produce creative science and technology workers capable of the innovation presumed to be necessary to support a healthy and prosperous society. Additionally, students, who otherwise may be unwilling or unable to pursue a traditional science or technology degree, may be interested in pursuing a degree in such hybrid programs. Graduates of such programs would supplement and complement those of more traditional science and technology programs. Students approaching such programs from a primarily arts and humanities perspective may be among the most creative, innovative program graduates, and they would also gain ample background in science and technology, further boosting the nation's literacy in science and technology. Finally, the gulf between the two cultures may become a little less wide with each attempt to harness both to a common goal.

Second, some may find it distasteful to direct increased funding toward relatively new interdisciplinary fields. Even Snow confessed his preference for the rigorous, traditional academic disciplines:

> But nevertheless I was slow to observe the development of what, in the terms of our formulae, is becoming something like a third culture. I might have been quicker if I had not been the prisoner of my English upbringing, conditioned to be suspicious of any but the established intellectual disciplines, unreservedly at home only with the 'hard' subjects. For this I am sorry.[65]

Here, rather than funding interdisciplinary fields per se, specific large social problems, with solutions that likely may draw from multiple disciplines, could be funded instead. A prime example would be using science and technology to cope with an increasingly elderly population. Pollack reported on the aging of the world population and on current efforts to assist the elderly using intelligent technology that monitors them for well-being, allows them to compensate for cognitive deficits, and assesses their cognitive capabilities.[66] Referring to U.S. "baby boomers" specifically and the prospect of new kinds of prosthetics, Brooks claimed:

> …baby boomers are getting older, and their nervous systems are starting to fall apart. There will be increased demand for patching up deteriorating nervous subsystems – and baby boomers have always gotten what they demand.[67]

[65] Snow, *The Two Cultures: And a Second Look*, 70.
[66] Martha E. Pollack, "Intelligent Technology for an Aging Population: The Use of AI to Assist Elders with Cognitive Impairment", *AI Magazine* 26, no. 2 (2005): 9-24.
[67] Rodney Brooks, "Toward a Brain-Internet Link", *Technology Review*, November 2003, 30.

The success of such programs will require the participation of more than just scientists and technologists. For example, technologies may need to be aesthetically pleasing in order to ensure their use.[68] Availability of brain and nervous system prosthetics would spark ethical debates. In short, funding certain large problems may unite a variety of disciplines from across the two cultures, while simultaneously stimulating U.S. science and technology.

**Conclusion**

In the U.S., deficiencies in K-12 mathematics and science education, coupled with a perceived decline of U.S. science and technology relative to that of other nations may intensify the two cultures problem. However, this need not be the case. Attempts to reverse the perceived decline in science and technology could work to unite the two cultures, if some of the probable new funding is directed toward certain interdisciplinary fields and problems. In some interdisciplinary fields, the component disciplines have to some extent learned to work together toward a common goal. Additionally, some interdisciplinary fields are well-poised to produce the broadly-trained, creative scientists and technologists needed to make the new discoveries and develop the innovative technologies and products that add new jobs and fuel the economy. Finally, certain interdisciplinary science and technology programs may attract and retain students not interested in pure science or technology alone. Interdisciplinary fields demonstrate that the two cultures problem need not be a zero-sum game.

**Reference List**

Aspray, William, Frank Mayadas, and Moshe Y. Vardi, eds. 2006. *Globalization and offshoring of software (summary and overview version).* Association for Computing Machinery, ACM Job Migration Task Force.

Braswell, J.S., A.D. Lutkus, W.S. Grigg, S.L. Santapau, B.S.-H. Tay-Lim, and M.S. Johnson. 2001. *The nation's report card: Mathematics 2000.* Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement, National Center for Education Statistics.

Brooks, Rodney. November 2003. Toward a brain-Internet link. *Technology Review*. 30.

[68] Jennifer Preece, Yvonne Rogers, and Helen Sharp, *Interaction Design: Beyond Human-Computer Interaction* (New York: John Wiley & Sons, 2002).

Bush, George W. January 31, 2006. *State of the union address*. http://www.whitehouse.gov/stateoftheunion/2006/print/index.html (accessed March 12, 2006).
Business Roundtable. 2005. *Tapping America's potential: The education for innovation initiative*. Washington, DC: Business Roundtable.
Chin, Spencer. April 6, 2006. Rep. Boehlert urges full U.S. science funding. *EETimes Online*. http://www.eetimes.com/ (accessed April 7, 2006).
Fuller, Douglas B. April 7, 2006. The fact remains, U.S. tech leadership must be reinforced. *San Jose Mercury News*. http://www.mercurynews.com/ (accessed April 7, 2006).
Gardner, Howard. 1987. *The mind's new science: A history of the cognitive revolution*. New York: BasicBooks.
Gereffi, Gary, Vivek Wadhwa, Ben Rissing, Kiran Kalakuntla, Soomi Cheong, Qi Weng, and Nishanth Lingamneni. 2005. *Framing the engineering outsourcing debate: Placing the United States on a level playing field with China and India*. Duke University, Master of Engineering Management Program.
Glass, Robert L. 2006. Is the crouching tiger a threat? *Communications of the ACM* 49, no. 3: 19-20.
Grigg, W., M. Lauko, and D. Brockway. 2006. *The nation's report card: Science 2005*. Washington, DC: U.S. Department of Education, National Center for Education Statistics, U.S. Government Printing Office.
Indiana University. http://www.informatics.indiana.edu/ .
Johnson, Jean, Ana Maria Arumi, Amber Ott, and Michael Hamill Remaley. 2006. *Reality check 2006: Are parents and students ready for more math and science?* Public Agenda, Education Insights. http://www.publicagenda.org/research/pdfs/rc0601.pdf.
Johnson, Kristina M. January 8, 2006. U.S. engineers hold their own. *Philadelphia Inquirer*. http://www.philly.com/ (accessed January 9, 2006).
Longino, Helen E. 1990. *Science as social knowledge: Values and objectivity in scientific inquiry*. Princeton, NJ: Princeton University Press.
National Academies. 2006. *Rising above the gathering storm: Energizing and employing America for a brighter economic future, pre-publication version, February 2006 edition*. Washington, DC: National Academies Press.
Okasha, Samir. 2002. *Philosophy of science: A very short introduction*. New York: Oxford University Press.
O'Sullivan, C.Y., M.A. Lauko, W.S. Grigg, J. Qian, and J. Zhang. 2003. *The nation's report card: Science 2000*. Washington, DC: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics.
Perie, Marianne, Wendy S. Grigg, and Gloria S. Dion. 2006. *The nation's report card: Mathematics 2005*. Washington, DC: U.S. Department of Education, National Center for Education Statistics. http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2006453.
Pollack, Martha E. 2005. Intelligent technology for an aging population: The use of AI to assist elders with cognitive impairment. *AI Magazine* 26, no. 2: 9-24.
Preece, Jennifer, Yvonne Rogers, and Helen Sharp. 2002. *Interaction design: Beyond human-computer interaction*. New York: John Wiley & Sons.
Rotherham, Andrew J. and Kevin Carey. April 20, 2006. Expand the pool of America's future scientists. *The Christian Science Monitor*. http://www.csmonitor.com/ (accessed April 20, 2006).
Samuelson, Robert J. February 22, 2006. A phony science gap? *Washington Post*. http://www.washingtonpost.com/ (accessed February 22, 2006).
Snow, C.P. 1959. *The two cultures and the scientific revolution*. New York: Cambridge University Press.
--------. 1965. *The two cultures: And a second look.* Cambridge: Cambridge University Press.
Thagard, Paul. 2005. *Mind: Introduction to cognitive science, 2nd edition*. Cambridge, MA: The MIT Press.
U.S. Department of Education, National Center for Education Statistics. 2004. *Comparing NAEP, TIMSS, and PISA in mathematics and science*. Washington, DC: U.S. Department of Education, National Center for Education Statistics.
--------. 2005. *The condition of education 2005*. Washington, DC: U.S. Department of Education, National Center for Education Statistics, U.S. Government Printing Office.
Vegso, Jay. 2005. Interest in CS as a major drops among incoming freshman. *Computing Research News* 17, no. 3: http://www.cra.org/CRN/articles/may05/vegso.html (accessed March 12, 2006).