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THE COST TO THE NATION OF UNDERINVESTMENT IN EDUCATIONAL R&D

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"The United States is the strongest economy in the world, yet it faces ongoing challenges. Our educational system underperforms, especially at the lower levels; we no longer have the best schools in the world. We fail to invest enough in research and development. We are no longer on the cutting edge for many new ideas. We do not know how to maximize the use of many of our new information technologies; many of them sit on the shelf and contribute little to ongoing education or human improvement.

My colleague Thomas Stratmann has written a stimulating paper on how we might address all of these problems with one coherent policy. Thomas is one of the leading economists in the field of public choice or the interface between economics and politics. He has given this area close study, and I urge you to think very carefully about his recommendations."

– Tyler Cowen±

Executive Summary

Over the past thirty years, by many measures, U.S. student educational performance has not improved. Some measures of educational achievement have actually decreased. This development is coupled with a dramatic decline in the productivity of educational spending: As a nation, we spend more and more to obtain the same level of educational achievement. Other industrialized countries do much better than the U.S. when comparing educational performance and the productivity of educational spending. With respect to educational achievement, the position of the U.S. relative to other countries is deteriorating. While the U.S. ranked 22nd among 27 industrialized countries in the 2000 PISA math study, it ranks 24th of 29 countries in the 2003 study.

Despite the decline in educational performance, federal educational research and development (R&D) expenditures are very low. Over time, these educational R&D expenditures have become

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a smaller and smaller fraction of total R&D expenditures. Educational R&D comprises only 0.01 percent of total R&D expenditures.

Research and development investments generate innovations that lead directly to increased productivity and to stronger economic growth. At the same time, innovators capture only a tiny fraction of the total financial returns from their innovations. This provides only a weak incentive for entrepreneurs to invest in R&D. For educational innovations such as software, the fraction of returns captured by the innovator is even smaller than the returns for many other innovations. Educational software, for example, is easily copied by competitors while it is expensive to develop. This results in an underinvestment in educational R&D.

However, educational R&D efforts produce innovations that transform learning and result in better educational performance. These innovations will help adults rapidly acquire skills needed in the new economy. Studies conducted over the last eight years have demonstrated that for primary and middle school students, the introduction of technology into the educational process has undoubtedly been beneficial; using currently existing software tools resulted in a significant improvement in student academic achievement scores. For example, research shows that integration of new technologies into public schools has a positive impact on academic performance in the core areas of reading, language and math.

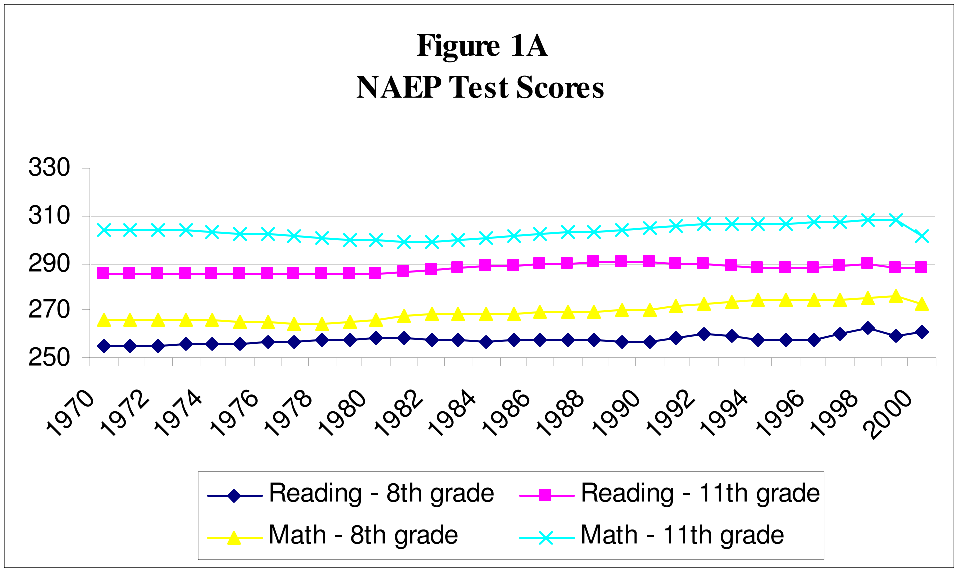
Allocating funds to solve the problem of underinvestment in educational R&D is an appropriate activity of the federal government. The Digital Opportunity Investment Trust Act proposes a Congressionally accountable competitive federal grant-making fund dedicated to research and development for education and training, predicated upon the successful model of the National Science Foundation (NSF). DO IT will create incentives for investment in educational R&D, resulting in innovations that transform teaching, guarantee lifelong learning and training through the use of advanced information technologies, and, most importantly, improve learning outcomes. DO IT will generate the tools necessary to assure that U.S. students acquire the knowledge and skills required for our country's future growth and prosperity. Newly developed learning tools will increase the productivity of education and educational achievements and are likely, therefore, to help improve the productivity of educational spending.

As a nation, we have neglected research and development in education. The Digital Opportunity Investment Trust will fill this gap. The DO IT Research and Development Roadmap shows how to develop programs that result in a transformation in teaching, lifelong learning and workforce training. Exploitation of emerging information technologies will accomplish this transformation. New learning tools will increase student achievement and enable all citizens to have the opportunity to learn new skills quickly.

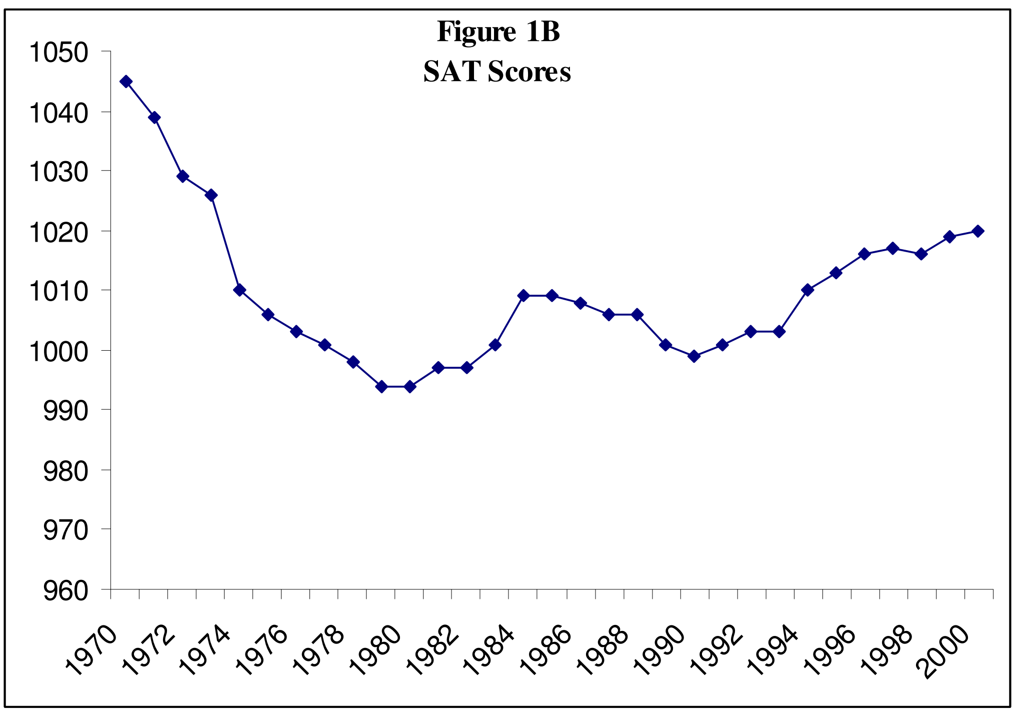
The Current Situation: Productivity in Education

Over the last thirty years, educational achievement in the U.S. has been flat or declining while productivity in education has fallen to all-time lows. The first point is illustrated by test scores from the National Assessment of Education Progress (NAEP) program.[1] For various age groups, these scores allow a comparison of educational achievement over time. Figure 1A plots the NAEP scores for math and reading of 8th and 11th graders. The graph shows that performance has been flat for both grade levels in those subjects.[2] An alternative measure of educational achievement is the SAT score. Figure 1B plots the evolution of SAT scores from 1970 onwards and shows that SAT scores declined in the 1970s. Although they increased by the year

2000, they are still below the levels of the early 1970s. By choosing 1970 as the starting point, the graph actually understates the decline because SAT scores started falling in the mid-1960s.



Sources: National Center for Education Statistics, Digest of Education Statistic, various years.



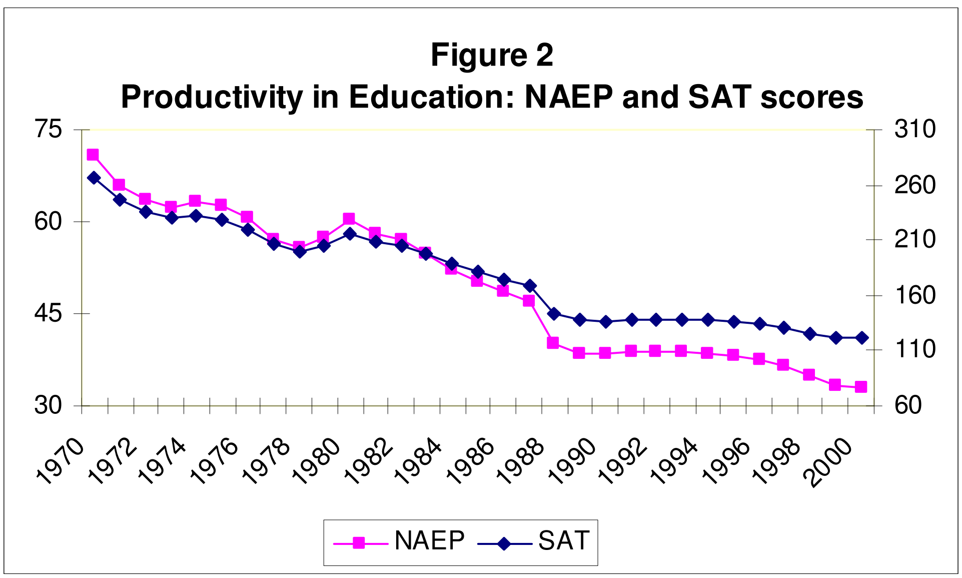
Sources: National Center for Education Statistics, Digest of Education Statistic, various years.

Is the disappointing pattern of educational performance in Figures 1A and 1B due to a lack of federal spending on education? It turns out that the flat or declining scores are not due to a lack of funding. Spending by the U.S. Department of Education was $180 billion in 1970 (in real 2000 dollars), increased slightly in the mid eighties, and rose steeply thereafter to $399 billion in

2000.[3]

A convenient way to examine the effectiveness of educational spending is to examine productivity in education. Productivity is measured by dividing outputs by inputs. In education, outputs are test scores, which are very good predictors of future earnings. The inputs are spending per pupil. Spending per pupil has increased over the past thirty years, and this trend follows the previously noted pattern in total education spending. In real 2000 dollars, spending per pupil has risen from $3,900 in 1970 to $8,400 in 2000.

After dividing test scores by spending per pupil (measured in thousands of dollars), Figure 2 depicts the pattern of productivity of educational spending since 1970. One graph in Figure 2 describes productivity based on an average of the four NAEP scores in Figure 1A, and another graph depicts the productivity based on the SAT scores in Figure 1B. The graphs clearly show that productivity of educational spending has declined in the U.S. over the past 30 years. With respect to NAEP scores, educational productivity has declined in the year 2000 by about 48% of its 1970 level.



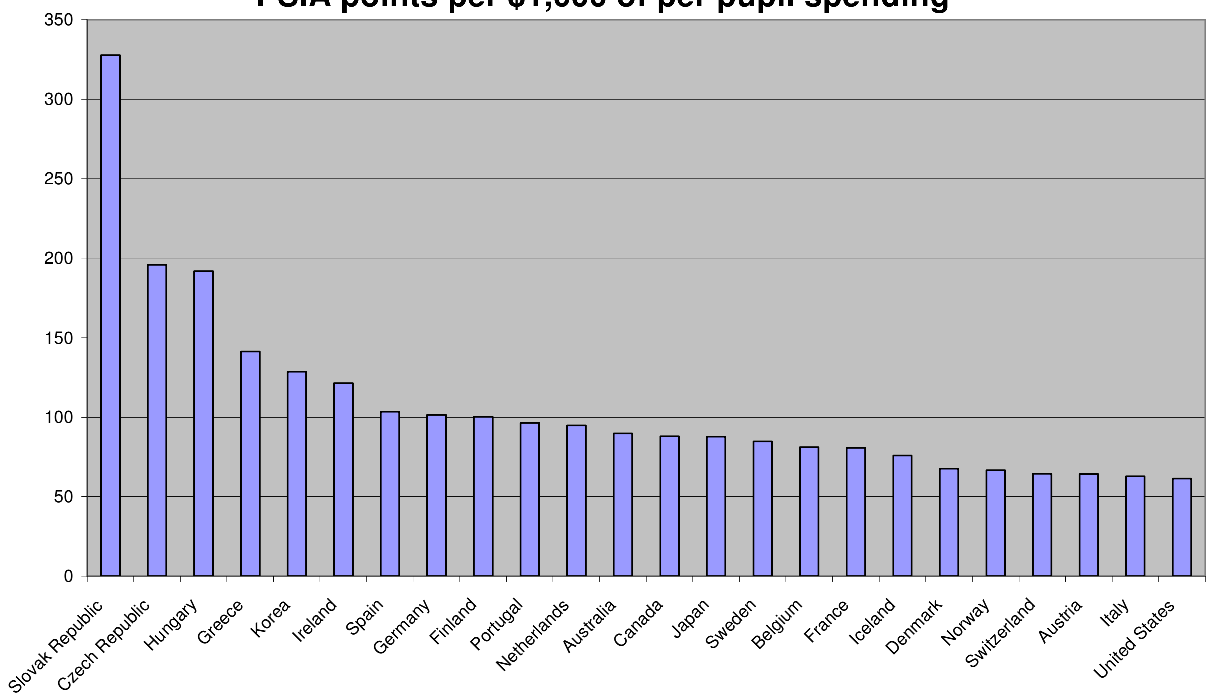
Productivity of NAEP scores on left axis, and productivity of SAT scores on right axis. The source for these data is National Center for Education Statistics, Digest of Education Statistic, various years.

The 1970s level of knowledge is not adequate to prepare students for a high-tech world. For students to be successful and meet the challenges of an information economy, test scores must increase. The declining productivity of educational spending shows that current methods of educational spending are not effective: scores are not increasing even though the U.S. spends more and more per pupil on education. This suggests that we have to find new and more effective methods of teaching.

How does the U.S. rank in international comparisons of educational productivity? Comparisons across nations can be made using the mathematics and reading scores from the Organization for Economic Cooperation and Development (OECD) Program for International Student Assessment (PISA). The PISA scores describe the educational achievement of 15-year-olds. These scores have the advantage of being comparable across countries and are thus suitable for productivity comparisons. One may be concerned that this sample is skewed because in some countries not all 15-year-olds are still in school; however, this is not the case for the countries examined here. Students in this age group are likely to be attending school in these countries.

The chart in Figure 3 ranks countries in terms of educational productivity, calculated by dividing each country's PISA scores from the year 2003 by its average expenditures per pupil from age 6 to 15 using purchasing power parity as the basis of currency conversion.[4] The chart shows that the U.S. ranks low in terms of productivity. This international comparison shows that American schools are among the least productive of the countries in Figure 3.[5]

Figure 3:
PSIA points per $1,000 of per pupil spending



Source: Organization for Economic Co-operation and Development, Program for International Student Assessment. (2003 survey)

As noted above, the productivity of education spending in the U.S. has declined by roughly 48% from 1970 to 2000 (see Figure 2). The data for Figure 3 imply that, in the year 2003, U.S. schools are approximately half as productive as schools in Finland, Ireland and Germany. This implies that the educational productivity in schools of those countries is roughly as high as the productivity in the U.S. some 30 years ago.

The reason that the U.S. lags behind other countries in terms of productivity is that while it spends large amounts on education, its educational achievement remains relatively low. For example, the U.S. lags behind Finland, Ireland, and Sweden with respect to educational productivity (see Figure 3) and PISA scores. When evaluating the PISA scores, the average of math and reading scores in 2000 are 545 for Finland, 515 for Ireland, and 514 for Sweden, while the U.S. score is 490. The fact that the U.S. is falling behind other countries with respect to educational attainment is one of the primary reasons the National Science Board has issued warnings that the U.S. is losing its scientific edge.

The importance of searching for new educational methods is amplified by the fact that the U.S. is lagging behind other countries in terms of educational achievement and in terms of productivity of educational spending. The development of new educational methods can increase productivity. To date, "the potential for research has not been realized" in the field of education and the practice of school education "does not rest on a strong research base."[6]

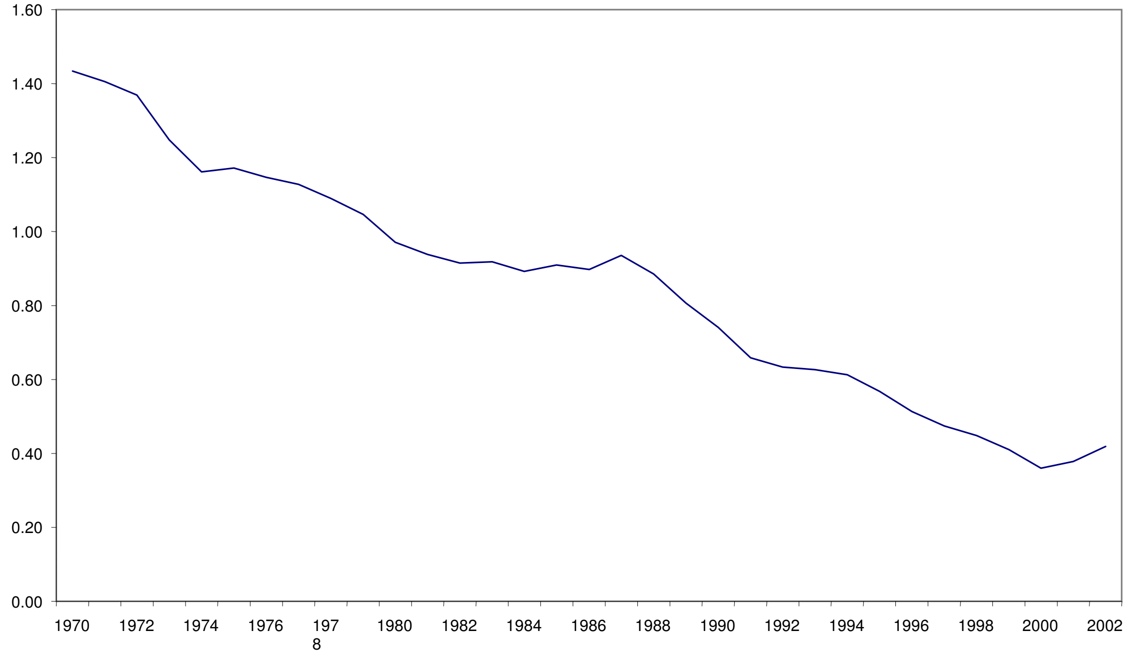
The Current Situation: R&D Spending for Education

R&D is a primary source for growing income and wealth. That R&D spending is effective has been documented in academic research. This body of work has shown that firms and industries with higher R&D spending also have improved productivity.[7] There is a strong positive relationship between industry R&D expenditures and productivity growth.[8]

Research and development in education generates methods that raise educational performance and productivity. A solid education is the foundation upon which we will build the future prosperity of our country. Unfortunately, our financial commitment to improving educational achievement through R&D is miniscule.

With few interruptions, overall federal R&D spending as a fraction of total industry R&D spending has been steadily falling (see Figure 4). This suggests that the federal commitment has been declining relative to the commitment of the private sector. Furthermore, in international comparisons, the U.S. is not the leader in R&D activities. For example, with respect to R&D to GDP ratios, the US ranks behind Japan, Sweden and Finland, and overall ranks in 5th place among OECD countries.[9]

Figure 4
Federal R&D Spending as a Percentage of Industrial R&D Spending from 1970 to 2002

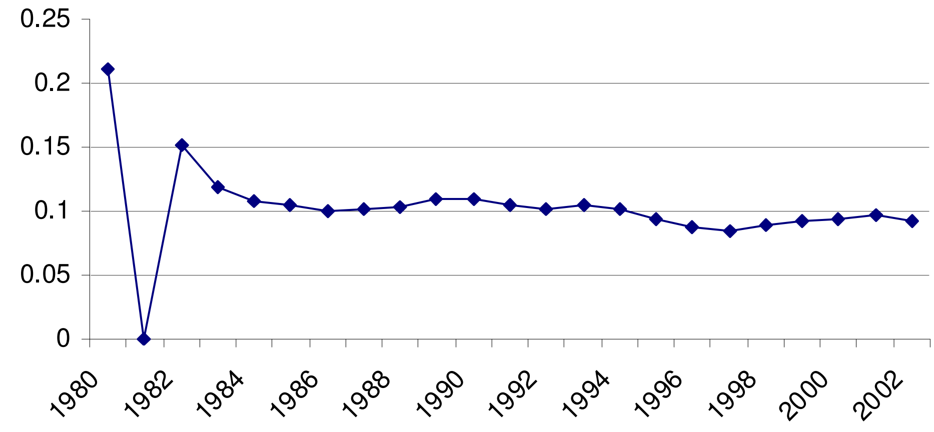


Source: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources.

Federally funded R&D has declined relative to industrial R&D. What's more, the portion of the federal budget devoted to educational R&D spending is very small. One proxy for R&D spending in education is the amount the Department of Education allocates to R&D. This is a broad measure and overstates the amount spent on developing new learning tools because it includes research spending on assessing the current state of education and other items. However, this measure has the advantage of being comparable over time.[10]

According to this measure, the federal government spent less than $270 million on the educational research and development in FY 2002. This accounts for about 0.09 percent of nationwide R&D spending. Figure 5 shows that prior to the mid 1990s, our nation spent about 0.1 percent of total (industrial and federal) R&D spending on educational R&D, and that this percentage has been declining. While the economy has become more computerized and the demand for skills has increased, there has been little commensurate additional investment in educational technology research and development to enable us to increase knowledge to improve educational performance and to develop the new skills demanded by the changing workforce.

Figure 5
Percent Investment in Educational R&D, 1980-2002



Source: National Science Foundation, Division of Science Resources Statistics, Survey of Federal Funds for R&D, Vol 50, (2002), and National Patterns of R&D Resources: 2002 Data Update, Table D.

Over the past twenty years, overall federal R&D activities and educational R&D have declined relative to total R&D activities (see Figure 4 and Figure 5). Furthermore, educational R&D spending has also become a smaller part of federal R&D spending.

This evidence shows that federal government spending on R&D has been declining over the past 30 years relative to spending on other sectors of the economy. Moreover, spending on educational R&D aimed at raising educational achievement and skill levels is only a tiny fraction of overall R&D spending. This is alarming because we know that more educational achievement and better skills translate into higher incomes, wealth and welfare for our citizens.

Economic Rationale for a Federal Education Investment Trust

Economics implies that when the private returns of economic activities are less than their social returns, there is an underinvestment in economic activity. Social returns from the investment are the benefits to the overall society. Private returns are the profits to the investor. Thus, whether there is an appropriate level of investment in educational R&D depends on the degree to which firms can capture the returns from their investments. The lower the return from the investment, the weaker the incentive to undertake R&D.[11] Firms will find expenditures on R&D activities worthwhile if they can capture a sufficient return from the investment.

The fact that firms cannot fully appropriate the returns from R&D investment leads to an underinvestment in innovation. Even though the U.S. and many other countries provide patents, copyrights and trademarks as incentives to innovate, competitors tend to legally "invent around" patents,[12] making the patent system less effective than the designers of patents envisioned. Entrepreneurs receive only a small part of the social benefit of innovation. In part, this is because the information about their innovations is in the hands of their competitors within about 12 to 18 months, on average.[13] If firms know that rivals can imitate new technology easily, the incentive to invest in R&D is attenuated. Imitation by competitors lowers returns and thus lowers, and in some cases eliminates, the incentive to invest in innovation.

When firms know that they are unlikely to be able to capture much of the returns of their R&D investments, their incentive to spend resources in this area leads to an underinvestment in new technologies. This, in turn, leads to lower economic growth. As pointed out by Nobel Laureate Robert Solow, much of growth comes from new technologies and new ideas.[14]

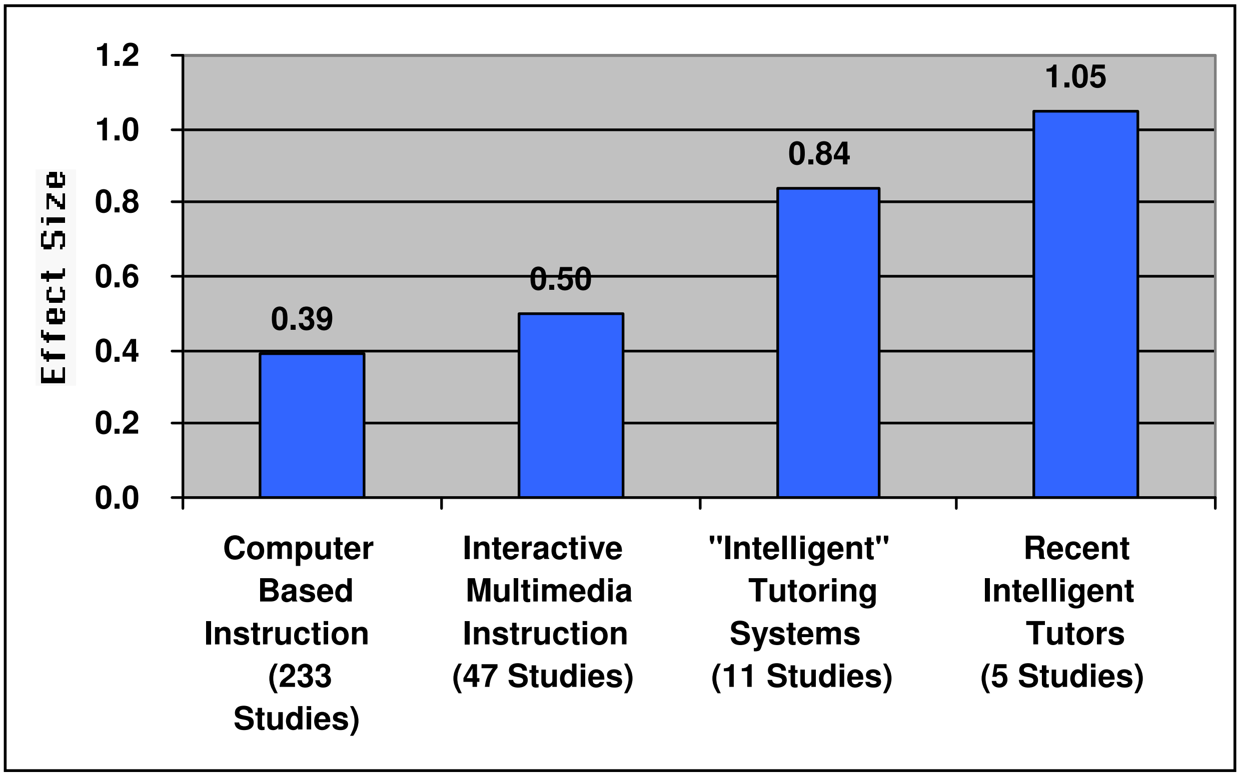
The difficulty of appropriating returns from innovations is widespread. Innovators receive only a tiny fraction of the social benefits from technological advances. Over the 1948 to 2001 period, innovators captured only 2.2 percent of the total present value of their innovations.[15] The vast difference between the total value and their share of the returns strongly suggests that many productive R&D activities are not undertaken because innovators can expect only a tiny fraction of the total returns of their inventions.

The degree to which intellectual property can be appropriated, and the ease with which innovation can be imitated, differs among industries. Innovation in educational technologies is a prime example of where it is difficult to obtain even a small fraction of the returns from the innovation. Innovative educational methods are readily observable and easily imitated. The ease of imitation of new methods is exemplified by the fate of many firms in the new technology economy in the 1990s. These firms quickly became bankrupt because their new business models, the software they developed and many of their other innovations were easily observable. The Internet makes the copying of these ideas and innovations especially easy. When competitors copy some or all of the new methods developed by other firms, the financial returns from the innovation can be very low. This provides only weak incentives to invest in the development of new methods. New information technologies are expensive to produce and inexpensive to reproduce. Private returns from investments to develop these technologies have always been far below their returns to society and the Internet has further reduced the cost of imitating, transmitting and distributing new information.

Research that leads to new insights on how to use the power of new information technology includes: work designing new approaches to pedagogy using simulations; combining the skills of teachers and content experts with artificial intelligence systems to personalize instruction and answer questions; and using the new technology tools to evaluate complex sets of skills. These and other basic areas may pay high social returns, but the results will be particularly difficult to protect as proprietary intellectual property. Underinvestment in research means that most educational applications of new technology fall far short of the capabilities provided to other major service enterprises.

Recent research has demonstrated that some of the more advanced features of technology-enabled education will reap undeniable benefits in student learning outcomes.[16] [17] Fletcher (1999) concentrates on the results of advanced technology introduced into courses (interactivity, intelligent tutoring systems, simulations, etc.) and indicates that this technology is beginning to pave the way towards increased student achievement: The results shown in Figure 6 suggest steady progress in learning outcomes. "The effect size of 0.50 for interactive multimedia instruction indicates an improvement of 50th percentile students to the 69th percentile of achievement. The effect size of 0.84 for intelligent tutoring systems indicates an improvement from 50th to 80th percentile achievement. The effect size of 1.05 for recent intelligent tutoring systems indicates an improvement from 50th percentile to 85th percentile achievement."

Figure 6
Some Effect Sizes for Technology-Based Instruction



The success due to the introduction of this technology has been the result not of a nationally coordinated R&D effort in the field, but to the disaggregated efforts of experts in a number of fields (education, cognition, computer science, etc.). The results that already exist strongly suggest that a more concentrated effort is needed to aggregate these resources to reap the full benefits of introducing more advanced technology into the educational process.[18]

Educational R&D expenditures harbor the great promise of increasing productivity, economic growth, and the well being of citizens. However, since this type of R&D generates information, and because the returns from information are particularly difficult to appropriate, investment levels are significantly below optimal levels. This provides the prime reason for government funding of the proposed federal Digital Opportunity Investment Trust (DO IT). DO IT will provide funds for educational R&D expenditures, thus filling an important gap that prevents the economy from growing faster.

It is inexpensive to "invent around" new education technologies and software. This of course implies that innovators in this R&D area can appropriate a smaller part of the social benefits than innovators in areas where new developments are more difficult to copy. One example demonstrating the ease of duplicating information in the new technology age comes from a comparison of the cost of imitating the Encyclopedia Britannica thirty years ago, to the cost today. Now it is inexpensive to reproduce this information, and in some cases it is free, as for example with Microsoft's online Encarta. DO IT will assure that educational innovations are developed, despite the threat of low returns, a risk private entrepreneurs may not be willing to take.

DO IT proposes the development of software and online applications that can be replicated and used by schools nationwide – software applications such as online tutoring, simulations, virtual field trips, etc. These are examples of quintessential innovation in the information sector for which rates of appropriation are especially low. DO IT proposes to develop a virtual library of physical processes. Again, this innovation is about generating information that can be easily duplicated -- the type of information in which private investors have very little incentive to invest.

Conclusion

Educational technology R&D spending is a crucial part of generating innovations in education. Documenting the benefits of educational R&D activities is an emerging field of research. Also, current work suggests that educational R&D spending can be effective in increasing student performance, and in addressing issues of stagnant or declining test scores, and lagging productivity.

The introduction of new digital technologies improves learners' attitudes and increases motivation as well as learning outcomes and learning activities.[19] Further, the introduction of computer education programs can lead to significant gains in reading, language and math. For example, the Idaho Council for Technology in Learning concludes, from a study of 35,000 8th and 11th grade students, that the integration of technology into Idaho's public schools had a positive impact on academic performance in the core areas of reading, language and math.[20]

The potential of digital technologies for educational achievement is reflected in studies reporting that the introduction of new digital technologies improves outcomes in reading, writing and math, with the largest gains observed in low income and rural students as well as girls.[21] These findings are so promising, and the need for improved educational achievement and productivity is so high, that we cannot afford NOT do adopt DO IT.

Endnotes

[1] The limitations of fixed-format testing are well understood and comparing the output of international educational systems adds additional levels of difficulty and controversy. Major projects include the *Trends in International Mathematics and Science Study* (TIMSS) and the *Program for International Student Assessment* (PISA) and the *Progress in International Reading Literacy Study* (PIRLS)**.** A detailed comparison of methodology and results is beyond the scope of the current study. A recent Department of Education study reviews differences in methodology and results (see Elois Scott and Eugene Owen, *Comparing NAEP, TIMSS, and PISA in Mathematics and Science*, International Activities Program, National Center for Education Statistics, U.S. Department of Education, January 2005). This review will use data from the Organization for Economic Cooperation and Development's *Program for International Student Assessment* (PISA) (see www.pisa.oecd.org) because it covers reading, mathematics, and science using a self-consistent approach.
[2] The NAEP test is administered every few years. The NAEP scores are interpolated for missing years.
[3] These figures do not include state and local spending.
[4] PISA scores and PPP spending data taken from OECD (see (see www.pisa.oecd.org). The facts documented in Figures 1 to 3 have also been documented in Hoxby, Caroline M. (2004). *Productivity in Education: The Quintessential Upstream Industry*, Southern Economic Journal, 72(1), pp. 209-231.
[5] To assure comparability across countries, this chart describes the productivity of spending for countries with an income of at least $10,000 per capita. The source for these data is the World Bank. World Development Indicators 2004. CD-ROM. Washington, DC.
[6] National Research Council. (1999). *Improving Student Learning: A Strategic Plan for Education Research and Its Utilization*.
[7] Adam Jaffe, Manuel Trajenberg, and Rebecca Henderson, (1993) *Geographical Localization of Knowledge Spillovers as Evidenced by Patent Citations*, Quarterly Journal of Economics, 108 (3), pp. 577-598.
[8] National Science Board: Science and Engineering Indicators 2004.
[9] Similar to DO IT, the Council on Competitiveness recognizes the importance of innovation for economic growth. The Council calls for increased funding for education and for innovations in many sectors of the economy (*National Innovation Initiative Report*, December 2004).
[10] The data for educational research and development expenditures represent the amount of federal funds that the federal government allocated through the Department of Education to different performers of research and development for R&D purposes.

[11] There is a vast literature discussing the relationship between social and private returns to innovation. This literature includes Zvi Griliches, *Research Expenditures and Growth Accounting*, in M. Brown, ed. (1973), *Science and Technology in Economic Growth*, New York, Wiley,; Zvi Griliches, (1986), *Productivity, R&D, and Basic Research at the Firm Level in the 1970s*, American Economic Review, vol. 76, pp. 141-54; Bronwyn Hall, *The Private and Social Returns to Research and Development*, in Bruce Smith and Claude Barfield, (1995), *Technology, R&D, and the Economy*, Brookings, pp. 140-183; Adam Jaffe, (1986), *Technological Opportunity and Spillover of R&D: Evidence from Firms' Patents, Profits, and Market Value*, American Economic Review, vol. 76, pp. 984-1001; Richard Levin, Alvin Klevorick, Richard Nelson, and Sidney Winter, (1987), *Appropriating the Returns from Industrial Research and Development*, Brookings Papers on Economic Activity, no. 3, pp. 783- 820; Edwin Mansfield, (1977), *Social and Private Rates of Return from Industrial Innovations*, Quarterly Journal of Economics, vol. 91, pp. 221-40; *Macroeconomic Policy and Technological Change*, in Jeffrey C. Fuhrer and Jane Sneddon Little, eds, (1996). *Technology and Growth, Conference Proceedings*, Federal Reserve Bank of Boston, , pp. 183-200; Edwin Mansfield et al., (1995), *Social and Private Rates of Return from Industrial Innovations*, NTIS, Washington, D. C.; and Nathan Associates, (1978), *Net Rates of Return on Innovation, Report to the National Science Foundation*.
[12] See, for example, Edwin Mansfield. (1980). *Basic Research and Productivity Increase in Manufacturing*, American Economic Review, Vol. 70, pp. 863-873.

[13] Edwin Mansfield. (1985). *How Fast Does New Industrial Technology Leak Out*? Journal of Industrial Economics, Vol. 34, pp. 217- 223.

[14] R.M. Solow (1956). *A Contribution to the Theory of Economic Growth*. Quarterly Journal of Economics. Vol. 70 (1) pp. 65-94.

[15] Nordhaus, William D. (2004). Schumpeterian Profits In The American Economy: Theory and Measurement NBER Working Paper 10433.

[16] Meta-analyses studying the effect of using technology-based instruction are readily available. For instance, Kulik (1994) has performed many such studies for technology-based instruction. From his own studies and those of colleagues, he reports an overall effect size of 0.35, which is roughly the effect of raising the achievement of 50th percentile students to that of 64th percentile students (as quoted in J.D. Fletcher [1999]. *The Case for Technology-Based Instruction: Some Research Findings*. Alexandria, VA: Institute for Defense Analyses p.5.).

[17] Kulik, J.A. (1994) *Meta-Analytic Studies of Findings on Computer-Based Instruction*. In E.L. Baker and H.F. O'Neil, Jr. (Eds.) Technology Assessment in Education and Training. Hillsdale, NJ: Lawrence Erlbaum Associates.

[18] Additional studies that support the effectiveness of educational software are: Gwaltney, T.L. (2000). *Year Three Final Report: The Lightspan Partnership, Inc. Project*. Report submitted to Lightspan in cooperation with Witchita Public Schools. Witchita, KS: Lightspan Partnership, Inc.; Koedinger, K., Anderson, J.R., Hadley, W.H., &Mark, M.A. (1997). *Intelligent Tutoring Goes to School in the Big City.* Paper presented at the 7th World Conference on Artificial Intelligence in Education, Washington D.C.; Sawyer, T.L. (1999). *A Study of the Use of Reading Software in the Classroom*. Unpublished Master's Thesis. Johnson Bible College, Knoxville, TN.; Vollands, S. R., Topping, K.J., & Evans, R.M. (1999). *Computerized Self-Assessment of Reading Comprehension with the Accelerated Reader: Action Research.* Reading & Writing Quarterly, 15, 197-211.; MacIver, D.J., Blafanz, R., & Plank, S.B. (1998). *Report No. 21: The Talent Development of Middle School: An Elective Replacement approach to providing extra Help in Math – The CATAMA Program (Computer – and Team-Assisted Mathematics Acceleration).* Washington, D.C.: Johns Hopkins University.; Scott, L.S. (1999). *The Accelerated Reader Program, Reading Achievement and Attitudes of Students with Learning Disabilities.* Unpublished Dissertation, Georgia State University, Atlanta, GA; Waterford Institute. (1999). *Evaluation of the Waterford Early Reading Program Level 1: Norwalk Public Schools—Norwalk, CT, 1998-99 School Year.* Sandy, UT: Evaluation and Assessment Division, Waterford Institute.

[19] O'Hara, S. P. (1998). *A Case Study of Attitudinal Effects of Internet Use in a Middle School Integrated Science Curriculum*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, San Diego, CA, April 19-22.; Richards, F. C. (1996). *The Impact of the Internet on Teaching and Learning as Perceived by Teachers, Library Media Specialists and Students*. Unpublished Masters thesis. Salem-Teikyo University; Chessler, M., Rockman, S., and, Walker, L. (1998) *Powerful Tools for Schooling: Second Year Study of the Laptop Program*. San Francisco: Rockman; Sandholtz, J. H., Ringstaff, C. & Dwyer, D. C. (1997). *Teaching with Technology: Creating Student-Centered Classrooms*. New York: Teachers College Press; Means, B. (1998). *Models and Prospects for Bringing Technology-Supported Education Reform to Scale*. Paper presented at the annual meeting of the American Educational Research Association, San Diego, CA. Available: http://www.sri.com/policy/ctl/html/context3.htm; Jeffrey T. Fouts (2000). *Research on Computers and Education: Past, Present and Future*. Prepared for the Bill and Melinda Gates Foundation. Follansbee, S., Gilsdorf, N., Stahl, S., Dunfey, J., Cohen, S., Pisha, B., and Hughes, B. (1996). *The Role of Online Communication in Schools: A National Study*; Peabody, MA: Center for Applied Special Technology; Tierney, R. J., Kieffer, R., Stowell, L., Desai, L. E. & Whalin, K. (1992). *Computer Acquisition: A Longitudinal Study of the Influence of High Computer Access on Students' Thinking, Learning, and Interactions.* ACOT Report #16. Cupertino, CA: Apple Computer; Tierney, R. J. (1996). *Redefining Computer Appropriation: A Five-Year Study of Acot Students.* In C. Fisher, D. C. Dwyer & K. Yocam, Eds. *Education and Technology: Reflections on Computing in Classrooms*. San Francisco: Jossey-Bass. pp. 169-183; Williams, D. C. (1999). *The Effects of Expert Stories on Sixth Grade Students' Achievement and Problem Solving in Hypermedia-Supported Authentic Learning Environments (HALE).* In *Proceedings of ED-MEDIA/ED-TELECOM 99 World Conference on*

Educational Multimedia and Hypermedia & World Conference on Educational Telecommunications. pp. 112-118, Charlottesville, VA: Association for the Advancement of Computing in Education.

[20] Idaho Council for Technology in Learning (1999). The Idaho Technology Initiative: An Accountability Report to the Idaho Legislature on the Effects of Monies Spent Through the Idaho Council for Technology in Learning. The State Division of Vocational Education, The State Department of Education, Bureau of Technology Services.

[21] Mann, D., Shakeshaft, C. Becker, J. & Kottkamp, R. (1999). *West Virginia Story: Achievement Gains from a Statewide Comprehensive Instructional Technology Program.* Santa Monica, CA: Milken Family Foundation.