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COMPUTERS IN SCHOOLS AND COGNITIVE ACHIEVEMENT

A SUMMARY OF THE RESEARCH

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Abstract: This research summary describes what we know about the relationship between students' use of computers at school and their cognitive test scores. It also briefly discusses the usefulness of teaching computer literacy in schools. While access to computers is a necessary condition for their use, access does not guarantee that students will use the

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computers, and getting students to use computers does not guarantee that they will use them in ways that improve their cognitive achievement. When students do use computers in school it is generally to search the Internet, work on group projects, or to use the Internet to do homework. Research shows that programs that increase the number of computers in schools have had little effect on students' test scores. However, a growing body of research does suggest that when computers are used to provide instruction test scores in reading and math increase. This kind of computer instruction is not very common in most countries and even in the United States computer instruction is rarely routinely used in schools.

Keywords: computers in schools, cognitive achievement, Computer-assisted instruction.

In almost every country the number of schools with computers and the ratio of computers-to-students in schools have increased rapidly in the last 20 years, and in most countries the amount of money spent on computers, Internet access and software in schools has increased both absolutely and as a percent of educational spending. Advocates have provided many reasons for putting computers in schools but three of the most common rationales are to teach computer literacy and reduce the "digital divide; to revolutionize teaching and learning by harnessing the information and communication capabilities of computers and the Internet; and to provide instruction in core academic subjects such as mathematics and reading.

I emphasize the effect of access to and use of computers on test scores rather than on other outcomes partly because this is the outcome studied in most of the high-quality research and partly because in most countries the "problem" as defined by parents, employers, and governments is that students too often fail to learn basic skills in school. Furthermore, in every country where it is measured the labor market rewards math and reading skill so these are clearly important for individual economic well-being and for economic growth. Some educators will object to this narrow focus. Indeed as I discuss below many advocates believe that computers in the classroom are valuable because they promote important skills not usually measured by test scores including critical thinking, creativity, collaboration, and intellectual motivation. The emphasis on test scores in this summary does not imply that these skills are unimportant only that they are seldom measured.

Overall the evidence suggests that programs to increase the number of computers in schools will not alone result in higher test performance among students. Students mainly use school computers to access the Internet and to do homework. These uses of computers may do little to increase test scores. Most research evidence concludes that computer-based instruction in mathematics and literacy raises test scores in these subjects. However, the evidence is not always strong, the effect sizes vary greatly across studies, and the vast majority of the research has been done in the United States.

This paper proceeds as follows: The next section provides background on the increase in access to computers in schools and describes major rationales for having computers in schools. Section II discusses the research and Section III concludes.

I. Introduction

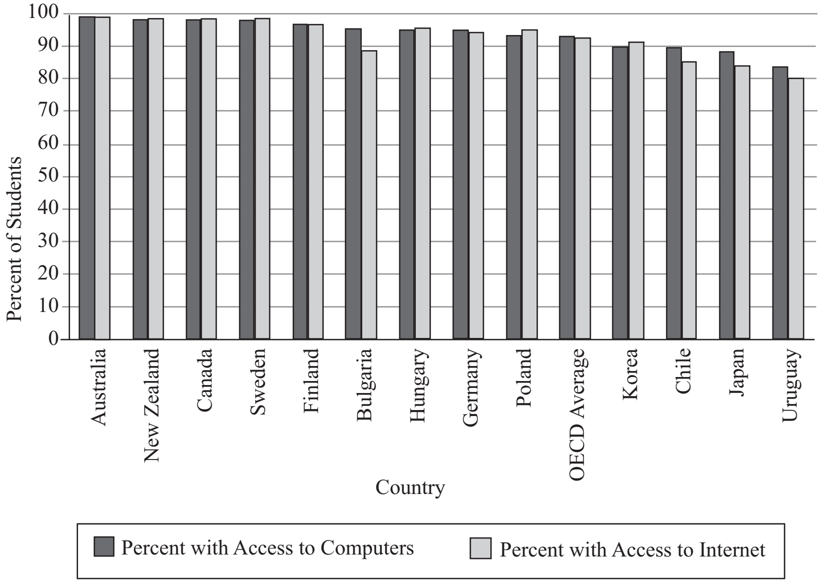
Figure 1 shows that in the richer OECD countries nearly all students report having access to computers and the Internet at school.[1] In the United States and United Kingdom (not included in Figure 1) virtually every school has had instructional computers in classrooms since 2005 (Grey, 2010). But even in less rich countries including Bulgaria, Hungary, Chile and Uruguay over 80 percent of students report having access to computers and the Internet at school[2].

How much access to computers students have depends in large part on how many computers are available to students. Figure 2 shows

[1] No information on student access to computers in either the United States or the United Kingdom is available from 2009 PISA data.

[2] GDP per capita in Hungary and Bulgaria is similar to GDP per capita in Chile, which is greater than GDP per capita in Uruguay. Of 45 countries with data on access to computers and the Internet in PISA 2009, only 1 country (Panama) had fewer than 80 percent of students reporting access to computers in schools. The next smallest percent was Uruguay at 83.8 percent. Out of the same set of countries five had fewer than 80 percent of students reporting access to the Internet at school (Italy, Turkey, Panama, Serbia and Uruguay).

FIGURE 1: PERCENT OF STUDENTS WITH ACCESS TO COMPUTERS AND THE INTERNET AT SCHOOL FOR SELECTED COUNTRIES, PISA 2009

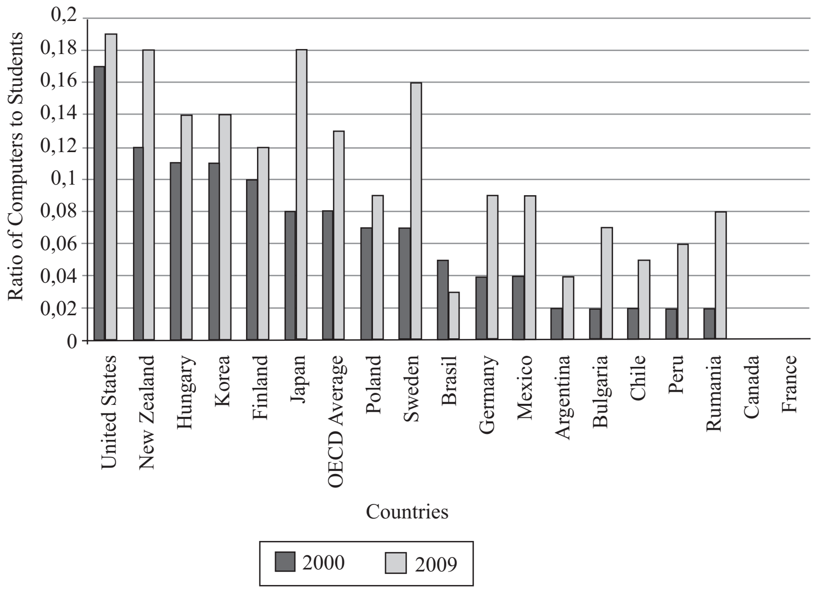


Source: PISA 2009 Results: Students On Line: Digital Technologies and Performance (Volume VI), OECD 2011, Table VI.5.9.

that the OECD average computer-to-student ratio in 2009 was about .13 (or 7.5 students per computer). This was almost double the ratio on 2000. Every country except Brazil increased the computer-to-student ratio between 2000 and 2009. The ratio in Chile increased from .02 to .06 but it increased more in Bulgaria, Peru and Romania, all of which had about the same ratio as Chile in 2000.

The usefulness of computers depends not only on whether students have access to them but also on how often and how students use the computers. The Program for International Student Assessment (PISA) survey asked fifteen-year-olds enrolled in school how much time they spent in a typical week using computers in classes on the language of instruction in their school, mathematics and science. Across OECD countries 84.2 percent of students report never using a computer in mathematics class, 75.4 percent report never using a computer in science class, and 74.0 percent report never using a computer in their class on the language of instruction. In Chile 83 percent of students said they never used a computer in their Spanish classes, 89 percent said

FIGURE 2: RATIO OF COMPUTERS TO STUDENTS BY YEAR FOR SELECTED COUNTRIES, PISA 2009



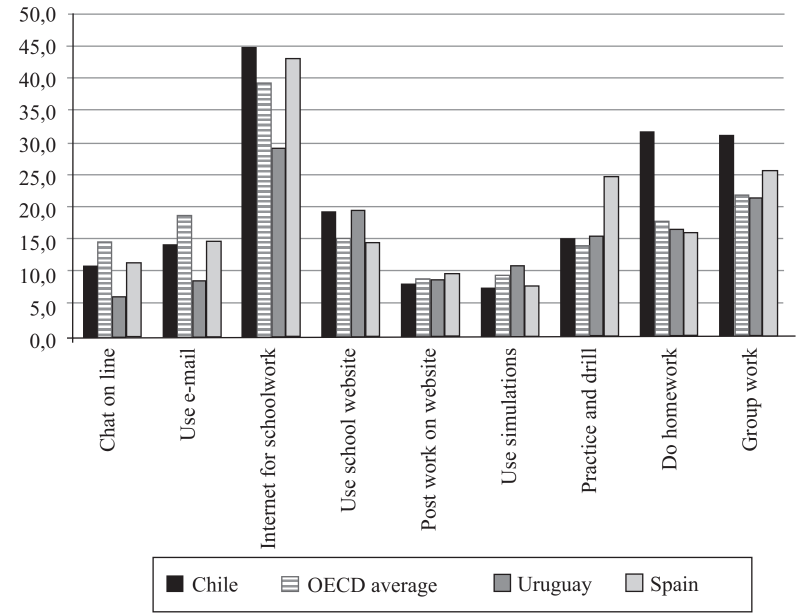
Source: PISA 2009 Results: Students On Line: Digital Technologies and Performance (Volume VI), OECD 2011, Table VI.5.

they never used computers in their mathematics classes and 83 percent said they never used computers in their science classes in a typical week of school[3].

Figure 3 shows results from the 2009 PISA on how students use computers at school when they do use them. It shows results for all OECD countries, for Chile and for Uruguay (the only other South American country in the data set) and for one European country, Spain. Fewer than half of students reported doing each of these activities at least once a week. When students use computers at school the most frequent thing they do is "browse the Internet for schoolwork." In OECD countries 39.2 percent of students reported doing this at least

[3] PISA assesses fifteen-year-olds enrolled in school. In countries where a high proportion of fifteen year olds are not in school, test scores and other data collected by PISA will not be representative of all fifteen-year-olds and it will not be comparable to test scores and other data collected in countries with higher rates of school enrollment among fifteen-year-olds.

FIGURE 3: A COMPARISON OF HOW STUDENTS USE COMPUTERS IN SCHOOLS



Notes: Full titles for categories are:
Chat on line: "Chat on line at school."
See e-mail: "Use e-mail at school."
Internet for schoolwork: "Browse the Internet for schoolwork."
Use school website: Download, upload, or browse material from the school's website.
Post work on website: "Post work on the school's website."
Use simulations: "Play simulations at school."
Practice and drill: "Practice and drilling, such as for foreign language learning or mathematics."
Do homework: "Do individual homework on a school computer."
Group work: "Use school computers for group work and communication with other students."

Source: PISA 2009 Results: Students On Line: Digital Technologies and Performance (Volume VI), OECD 2011, Table VI.5.17.

once a week compared to 44.7 percent of students in Chile, 42.9 percent in Spain and 29.1 percent in Uruguay. The next most common use of computers is to "do individual homework on a school computer." Again students in Chile are more likely than the average OECD student to do this. Chilean students are also more likely than the average OECD student to use school computers for "group work and communications with others."

Advocates and policy makers have articulated at least three rationales for having computers in schools: to teach computer literacy and narrow the digital divide, to "revolutionize" the way teachers teach and students learn, and to provide instruction in academic subjects as part of either virtual schooling or the traditional classroom. These three rationales do not exhaust all the ways computers might improve schooling[4]. For example, another important rationale might be cost saving. Standardized exams could be given and graded quickly and cheaply if students took them on-line. Because the rationale for computers in schools influences what we would expect access to computers to accomplish, I briefly discuss the three main rationales.

*Teach technological literacy***.** Historically, an important motivation for having computers in schools was to improve technological literacy and narrow the "digital divide." Technological literacy includes knowing how to: a) use computer hardware and software; b) communicate effectively with electronic media (e-mail, Web sites, message boards, blogs, streaming media, etc.); c) compare and choose among information available in electronic formats; d) select and prioritize across technology applications; and, e) minimize risks associated with electronic communication.

According to this rationale, computers and the Internet are increasingly the primary means for communicating and obtaining information for everyday tasks and in the labor market. Therefore, technological literacy has become as important to economic and social well-being as numeracy and reading literacy[5]. By providing access

[4] Others have developed lists of rationales for using computers in schools. For example, Hawkridge (1990) described four rationales that drive policies related to the integration of ICT and the use of computers in education: 1) an economic rationale: the development of ICT skills is necessary to meet the need for a skilled work force, as learning is related to future jobs and careers; 2) a social rationale: this builds on the belief that all pupils should know about and be familiar with computers in order to become responsible and well-informed citizens; 3)an educational rationale: ICT is seen as a supportive tool to improve teaching and learning; and, 4) a catalytic rationale: ICT is expected to accelerate educational innovations. See also Rochell *et al.* (2001) and Laval and Hinostoza (2002).

[5] The eEurope 2002 objectives of the Lisbon Summit stipulate that all school-leavers must be digitally literate in order to be prepared for a knowledge-based economy (Commission of the European Communities, 2000).

to computers and teaching computer literacy schools will improve students' job prospects, productivity and citizenship and reduce inequalities in life chances that arise from unequal access to technology.

Transform teaching and learning. A second and related rationale for having computers in schools is to transform the education process by changing how students and teachers get information and communicate with others. According to this rationale giving students access to a computer and the Internet opens the door to the vast world of information. Given such access students' become self-motivated learning entrepreneurs, collaborating in learning through social networking and multi-tasking in innovative ways that result in deeper understanding and better problem-solving skills. Once computers and the Internet are available to students, teachers can cease being the conduit of knowledge and instead become a general guide for the students' self-motivated development of knowledge.

The most enthusiastic advocates of computers for children claim that the mere presence of computers can increase learning. For example, Sugata Mitra who led the Hole in the Wall project in India writes that once students have access to computers, "Teachers simply need to design questions that evoke curiosity and interest, then sit back and admire as learning happens."[6] The mission statement of One Laptop per Child (OLPC) says that when children have access to a laptop they, "get engaged in their own education. They learn, share, create, and collaborate. They become connected to each other, to the world and to a brighter future."[7]

The idea that when students have access to computers they learn on their own has lead many people to believe that when schools make computers available to students, a revolution in teaching and learning will occur because students will become self-motivated to learn what interests them and they can learn at a pace that is their own. Teachers will no longer control the knowledge transmission process but will instead guide students in their self-education. This will lead to greater critical thinking skills among students. If this reasoning is correct,

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[6] Interview in The Guardian Monday 18 October 2010 at http://www.guardian.co.uk/education/2010/oct/18/sugata-mitra-slumdog-teach-self

[7] One Laptop Per Child website, mission statement at http://one.laptop.org/about/mission

students will know more when they have greater access to computers at school.

Primary instruction. A third rationale for having computers in schools is to provide traditional instruction that is more accessible, individualized and consistent than can be provided by face-to-face instruction. In this rationale computers are not intended to transform the traditional learning process but rather to improve that process. Computers can be used for traditional instruction in virtual classrooms and regular classrooms.

Computer-assisted instruction (CI, sometimes referred to as CAI) refers to students using a computer program that provides primary instruction and feedback on achievement in a subject in order to increase the students' knowledge of that subject. A formal theory of CI yields several predictions about the circumstances under which CI should be most beneficial (Barrow, Markham and Rouse, 2008). Imagine that a student's achievement in a subject depends on two things: how much instructional time the student receives in the subject and a set of individual student characteristics such as the student's social and economic background and cognitive skill level. More instructional time will lead to greater achievement holding constant these student characteristics.

Also imagine a classroom in which a teacher divides the total time available for instructional, $\bar{T}$ between group instruction, T_g, and individual instruction, T_i, such that for the teacher $T_g + \Sigma T_i \leq \bar{T}$. In other words the time that a teacher spends at school is the time she spends providing group instruction plus the sum of the time she spends individually with each student, which together is equal to or less than the total instructional time available. The total instruction time for student *s* is then: $T_{gs} + T_{is} \leq \bar{T}$. Put another way the instructional time that a student receives is the sum of the time the student receives individual instruction and the time the student receives group instruction. While the teacher is providing individual instruction to other students, *s* receives no direct instruction. We can denote this time as N for "no direct instruction." Therefore for student *s,* $N_s + T_{gs} + T_{is} = \bar{T}$. Students might spend N working on worksheet or on individual or group projects, but they might also spend the time day dreaming, socializing or disrupting the class. Therefore N may or may not be useful for improving students' achievement.

As long as any other student in this traditional classroom receives individual instruction, the total time for instruction for student s will be less than the total instructional time available in a day. Put another way, when a teacher provides individual instruction to any other student $N_s > 0$. Therefore, in the traditional classroom each student receives the maximum instructional time when no student receives individual instruction and all students receive only group instruction. If the quality of individualized instruction is greater than the quality of either group instruction or N, the teacher faces a trade-off between the quality and quantity of instruction each student receives: as the teacher increases T_i for one student she decreases instruction time for all other students. Note that individual instruction can include time the teacher spends disciplining individual students or otherwise providing individual attention to students.

Now we introduce CI into the classroom. The teacher continues to allocate time between group and individual instruction but while the teacher is with student *j* student *s* can receive direct instruction from the computer software, C. Thus the total instructional time for student *s* is now, $T_{gs} + T_{is} + CI_s = \bar{T}$. If the gains in skill from C are greater than the gains from N, students will achieve more in a class with CI than in a traditional class where the teacher spends any time in individual instruction because N will be replaced with higher-quality C. Similarly if the quality of CI is equal to or greater than the quality of group instruction, the teacher can substitute time on the computers for group instruction and increase achievement.

The assumption that the quality of CI is equal to or greater than the quality of group instruction may not hold for all subjects or all classes but it is likely to hold when classes are large or heterogeneous and when teachers are poorly trained, inexperienced, or when other factors make the quality of teachers" instruction low. Similarly the quality of CI is likely to be greater than the quality of N when teachers cannot adequately supervise or design the time students spend working independently.

Virtual schools or online schooling is a form of distance education. At the primary and secondary levels virtual schooling is more common in the United States than in most other countries. The United

States National Center for Education Statistics (2008) estimated that the number of primary and secondary public school students enrolled in a computer-based distance education course grew by 65 percent in the two years from 2002-03 to 2004-05. A more recent survey, estimated that more than a million primary and secondary students took online courses in the 2007-08 school year, although most take only one or two such courses. As of fall 2007 only eight states lacked accredited multi-district virtual school programs. Twenty-eight states had degree-granting online virtual high school programs. The largest of these, the Florida Virtual School, served over 60,000 students in 2007–08. This year one state mandated that all high school students take at least two high school classes online. In Canada as early as the 2003-04 school year 36 percent of secondary school students took at least one on-line course (Ertl and Plante 2004).

A virtual school or virtual course differs from traditional schooling mainly because of the physical media that links administrators, teachers, and students and not because of differences in pedagogy. Virtual schools and courses usually maintain the tradition of a teacher (or team of teachers) providing instruction, consultation, and grading. Virtual school programs often present material in traditional textbook style. Computers and the Internet are mainly used as a way to deliver traditional schooling.

Distance education for primary and secondary students has been suggested as a solution to many educational problems, including crowded schools, a shortage of courses for remedial or accelerated students, and a lack of qualified teachers in some locations. In some cases the cost-effectiveness of virtual learning is an important argument in its favor.

The fact that most students use school computers for browsing the Internet, doing homework on the Internet and doing group work and communicating with other students implies that the “revolutionize schooling” rationale is the most common rationale among teachers and school administrators. These activities are consistent with the view that giving students independent time to explore using computers will help them learn. Students report spending relatively little time using computers for “drill and practice,” which would be more consistent with the view that computers are useful for delivering instruction. The PISA questionnaire did not even ask students about the amount of time they spend receiving computer-based instruction, implying that those who constructed the questionnaires did not think that this was a relevant category.

II. The Research

Hundreds of studies of the use of computers, the Internet, and specific computer programs have been published and dozens are added annually. Numerous journals are dedicated to research on computers in schools[8]. The vast majority of these studies provide no insight into whether access to or use of computers, the Internet or software improves any educational outcome. For example, many studies describe how teachers and students respond to the introduction of computers, the Internet or software or survey teachers about their attitudes towards various aspects of technology (e.g. Tolani-Brown, 2001; Conlon and Simpson 2003; Demetraidis *et al*. 2003; Ertmer 2005). Many studies also provide what might be called a process evaluation of the introduction of new technologies. These studies count the number of schools receiving the technology or the number of users and frequency of use, usually as reported by students or teachers. Some case studies of specific small interventions assess how classroom practices but not student outcomes change in response to the intervention (e.g. Bosch 2009, Light *et al*. 2009, Harrison *et al.* 2002).

I focus on research that tries to estimate the causal effect of access to or use of computers, computers and the Internet or computer-based instruction at school on educational outcomes. Many studies purport to do this but use methods that are inadequate to establish that the estimated change in educational outcomes is causally attributable to the use of technology. On PISA assessments Finland and Korea are

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[8] Journals published in English include the *Digital Education Review, Journal of Computers and Education, Australian Journal of Educational Technology British Journal of Education and Technology, Canadian Journal of Learning and Technology, Education Technology Review, International Journal of Instructional Media, Journal of Educational Computing Research, Journal of Educational Technology and Society, Journal of Research on Technology in Education, Journal of Technology & Teacher Education*, and many more. This does not count the at least 15 journals on distant learning alone (published in Hong Kong, Turkey Spain, UK, US, Canada, India, France, Australia and the US).

always among the countries with the highest test scores in math and reading. South American countries like Chile and Argentina always score much lower. In 2009 Finland and Korea had one computer for every 7 or 8 students. Chile had one computer for about every 20 students and Argentina had one for about every 25 students. This of course does not mean that if Chile and Argentina increased the number of computers in schools their test scores would improve because many other differences between Chile and Argentina and Finland and Korea could account for the differences in test scores. To estimate the causal effect of computers in schools we must control all relevant differences between countries (or schools or classrooms) with and without computers.[9] Some studies control observed differences between students or schools when estimating the effect of technology on educational outcomes. This is generally an inadequate strategy because there is always the possibility that some relevant factor is omitted from the model and that some variable in the model is at least partly endogenous, meaning that it is partly caused by the difference in technology.[10] Some studies try to match students who use computers to students with identical characteristics who do not. The most rigorous way to do this is to use propensity score matching, which estimates a predicted probability of being in the "treatment" versus the "control group" based on observed predictors to create a counterfactual group. The extent to which this results in unbiased estimates of effect sizes depends on the quality of the matching process, which depends on the data available for the match.

[9] By relevant differences I mean all factors that are correlated with access to technology that also causes the outcome. The most obvious is the economic make-up of schools. More affluent schools provide greater access to computers. Because more affluent students also score higher on cognitive tests, we will observe a positive correlation between access to computers and test scores. The many factors that cause some children to have greater access to computers than others (e.g. how much parents value education, whether schools are in urban or rural areas, quality of school leadership and so on) there is always the possibility of "unobserved heterogeneity" in observational studies.

[10] In this case an endogenous factor is one that is partly the result of access to or use of the technology under study. If having computers in schools increases the teachers' proficiency with computers and teachers' proficiency with computers results in teachers doing a better job of teaching math, then controlling teachers' proficiency with computers will result in downwardly biased estimates of access to computers on math scores.

A variety of experimental and econometric techniques are available to increase confidence that estimated effects are causal. These include difference-in-difference, regression discontinuity, and instrumental variable models. Many of the best studies use randomized control trials (RCT). These studies introduce a technology "treatment" to a randomly selected group of students (or schools or classrooms) and observe the difference in outcomes between this group and a randomly selected control group that does not receive the treatment. A well-designed RCT is the best method for determining the effect size of a treatment. But many RTCs are not well-designed. For example many have sample sizes that are too small to detect substantively important effects. I focus on studies that use either well-designed experimental methods or econometric methods that increase confidence that estimated effects are causal.

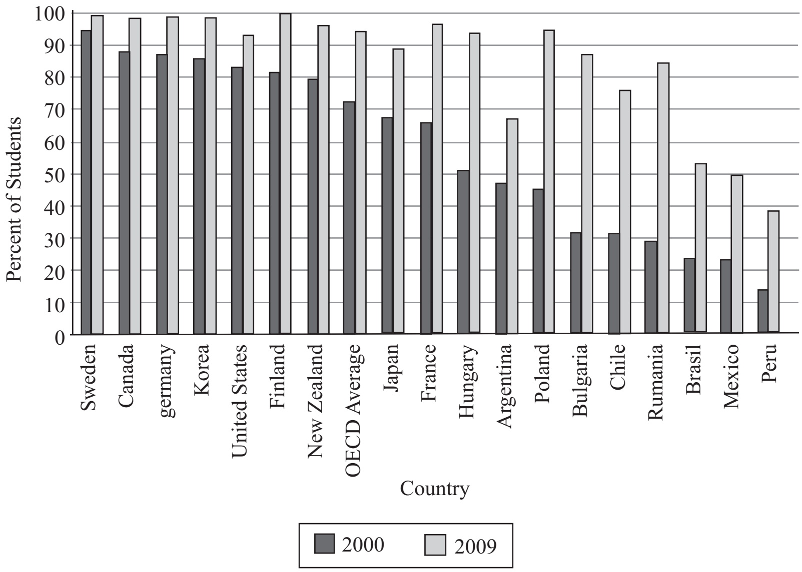
Technology has changed very rapidly in the last few decades. The hardware, software and Internet content have all changed dramatically. Studies of what happened even as recently as the 1990s or early 2000s may not be relevant to what is happening today. Consequently, I focus only on research since 2000. I do not conduct a formal meta-analysis. Below I describe the results of several meta-analyses that have been conducted and describe some problems typical of this approach to summarizing research.

This summary begins with a brief discussion of whether computers in schools increase computer literacy. The discussion is brief because there is little direct evidence to answer the question. I then turn to research that estimates whether students' test scores increase when they have access to computers at school and whether test scores increase when students use computer-based instruction.

Do computers in schools improve technological literacy?

It may seem inevitable that access to computers at school will increases students' computer literacy. But if students seldom use school computers, they are unlikely to learn much about how to use them. In addition even if students use school computers, they might learn most of what they know about computers from friends, relatives, or other sources outside of school. While little direct evidence is available,

FIGURE 4: PERCENT OF STUDENTS WITH A COMPUTER AT HOME BY YEAR, PISA 2009



Source: PISA 2009 Results: Students On Line: Digital Technologies and Performance (Volume VI), OECD 2011, Table VI.5.2.

indirect evidence suggests that schools do not play a major role in teaching computer literacy.

The availability of computers at home has increased dramatically even in less developed countries. Figure 4 shows the percent of students participating in the 2009 PISA who report having a computer at home in 2000 and in 2009 for selected countries and the average for OECD countries[11]. In 2009 the OECD average was over 90 percent. The countries where the fewest students had computers at home in 2000 gained the most between 2000 and 2009. In Chile about 75 percent of the students participating in PISA reported having a computer at home by 2009. When students use computers outside of school, the need for schools to teach computer literacy is likely to diminish. In addition,

[11] Sixty-four economies, mostly countries, participated in the 2009 PISA including Chile. PISA assesses the math, reading and science skills of fifteen-year-olds who are enrolled in school. See http://www.pisa.oecd.org/pages/0,3417,en_32252351_32235907_1_1_1_1_1,00.html (accessed 1/30/2012)

the more pervasive computers have become the more user-friendly they have become making it much easier for students to quickly master common computer programs. This also diminishes the need for schools to devote a lot of time in teaching computer literacy.

The Enlaces program in Chile is often cited as a model for the use of computer technology in middle development countries and computer literacy is an explicit rationale for having computers in schools in Chile. When a 2004 survey in Chile asked students who had taught them how to use the Internet, 55 percent replied that "their friends" had taught them, 34 percent said that "others" had taught them, 29 percent said that they learned by themselves, and only 9 percent said that they had been taught by their teachers (Hinostroza *et al.* 2005). This is a common finding in countries all over the world —much of the information about how to use computers and the Internet comes through "folk networks" and not through formal instruction in school.

This same survey found that students were more likely than teachers to say they were "very good" at using the computer for Internet browsing, creating presentations, and chatting. Teachers and students were about equally skilled at using email. More teachers reported that they were good at using educational software —only 17 percent of students said they were very good at this compared to 33 percent of teachers. Nonetheless this same survey found that schools are still the main place where students have access to computers in rural Chile. This suggests that while on average the need for schools to teach computer literacy may be declining, the availability of computers in schools (or other public places) may still be important for reducing the digital divide in rural or disadvantaged areas.

In the 2009 PISA all students took a paper-and-pencil reading assessment and a subset of students in 18 countries also took a computer-based reading assessment that required students to use skills needed for electronic media including navigation and search skills. Students who are familiar with using digital media should perform about equally well on the paper-and-pencil and digital assessments because the reading skill levels are similar for each. However, students unfamiliar with digital media are likely to perform worse on the digital assessment because they will not have the technological skills to use the digital programs. If schools play an important role in increasing technological literacy we would expect that students who attend schools with a high ratio of computers to students would perform better in digital reading than students who attend schools with fewer computers. However, after accounting for the socioeconomic background of students and the socioeconomic composition of schools students attending schools with an above average computer-to-student ratio scored the same on the digital reading assessment as students attending schools with a below-average computer-to-student ratio in both Chile and on average across the participating OECD countries[12]. Not all students who attend schools with computers actually use the computers. In Chile students who reported that they used computers at school scored no higher on the digital reading assessment than students who reported that they did not use computers at school. Across the OECD countries students who reported using computers at school scored on average 9 points higher on the digital reading assessment than students reporting that they did not use computers at school[13].

This suggests that schools are not improving the kind of technological literacy needed for the digital reading task. This may be because the level of technological literacy required for the PISA assessment was so low that almost all students had picked up these skills elsewhere or that it was possible to learn the skills quickly as they took the assessment. Schools might play an important role in teaching higher level or specialized technological skills for students who wish to learn these skills but most students seem to learn the basic skills needed to use digital media from other sources.

These PISA results are not definitive evidence on the role of schools in conveying technological literacy. However, the fact that computers have become more common at home, that students report learning to use computers mainly from sources outside of schools, and these PISA results taken together suggest that schools are playing a decreasing role in students' acquisition of general technological skills. However, a serious study would be required to estimate the needs of students for general technological skills and to understand what role schools can best play in helping them acquire these skills.

[12] PISA 2009 Results: Students On Line: Digital Technologies and Performance, Volume VI, Table VI.6.3.

[13] PISA 2009 Results: Students On Line: Digital Technologies and Performance, Volume VI, Table VI.6.4. The standard deviation of test scores on the digital reading assessment was 90 so a nine-point difference is equal to 10 percent of a standard deviation.

Does having access to computers and the Internet at school improve test scores?

The PISA results do not tell us much about whether access to a computer improves cognitive abilities because the digital reading assessment tested both reading ability and ability to use digital media. To see if access to computers improves test scores, I turn to studies that have evaluated programs that by chance increase the number of computers in some schools but not in others. Table 1 shows the results for seven such studies. These studies estimate the effect of programs intended to increase the number of computers available to students. They do not assess the effect of students using computers more or of using them for any particular purpose. The rationale for most of the programs evaluated by the studies in Table 1 was that if more computers are available students will use them more and if students use computers more their cognitive achievement will increase.

Of the seven studies across six countries in Table 1, only 1 study supports the claim that simply providing computers to schools results in improved cognitive skills among students. In that study Machin *et al*. (2005) use a change in the rules on ICT investment in English schools that occurred in 2001 to identify the effect of an increase in computers in the classroom and teacher ICT training on math and reading test scores. They find a positive effect of the additional computers and training on students' reading and science test scores (not math scores).

The last study listed in Table 1 (Christia *et al.* 2011) is notable because it is the only rigorous evaluation of the OLPC program. Fifteen months after OLPC computers were distributed in Peru the program had no measured effect on math or reading scores. However, children who received a computer had higher scores on the Raven's Progressive Matrices, which is a non-verbal measure of abstract reasoning. Recent evidence from a randomized experiment in Romania showed that having a home computer improved performance in the Ravens Progressive Matrices but resulted in lower cognitive test scores (Malamud and Pop-Eleches, 2011). These two studies imply that when students use computers their abstract reasoning skills improve but that the improved abstract reasoning skills do not result in improved scores on assessments of math and reading skill.

Observational studies suggest the possibility that there are diminishing returns to the use of computers in school for raising test scores. For example in a frequently cited study using PISA data, Fuchs and Woesmann (2005) find that after they control a set of school and family background factors the relationship between access to a computer at school and math or reading test scores is statistically insignificant. This is consistent with most of the evidence in Table 1. However, they also find that both students who seldom use computers at school and students who use them several times a week have *lower* reading and math scores than students who use computers for a moderate amount of time at school. This suggests a benefit to using computers at school but with diminishing (and then negative) returns, at least as computers are currently used. As noted above students who use computers in school mainly use them to access the Internet for schoolwork, to do homework at school, and to work on group projects with other students. These uses of school computers evidently do not contribute to increasing test scores.

Does computer instruction improve test scores?

Research on CI and virtual schooling differs from research on access to and use of computers because it focuses specifically on using software that is intended to teach academic subjects. As discussed above this is not the way computers are used at school by most students.

Determining whether CI increases cognitive achievement is a challenge. The mental experiment most people have in mind when they ask whether computer instruction "works" is whether students learn more when they receive instruction from a computer than they do if they receive instruction from a teacher in a traditional classroom. Given this mental experiment, whether CI "works" depends in part on what happens in the traditional classroom. CI is less likely to produce higher test scores than the traditional classroom experience when the traditional classroom has an excellent teacher, motivated students and families and high-quality educational materials compared to when the traditional classroom is of lower quality. Similarly, in developed countries most classes now have computers. When researchers introduce a new CI program to some schools (or classrooms) but not to others in a control group, students in the control group will probably

TABLE 1: EXPERIMENTAL AND QUASI-EXPERIMENTAL STUDIES OF THE EFFECT OF ACCESS TO COMPUTERS ON TEST SCORES

Author (Year)	Country	Intervention	Model notes	Result of additional computers
Author (Year) Angrist and Lavy (2002)	Israel	State lottery funded computers in some but not all schools	Randomized experiment	No benefit and possible negative effect of receiving funding for computers on achievement
Goolsbee and Guryan (2006)	US, California	E-Rate program - A government subsidy for Internet and communications software in schools	IV estimate using the Internet subsidy rate as the instrument	The subsidy increased Internet access but had no effect on achievement
Leuven *et al*. (2004)	Netherlands	Government-funded program to provide either extra personnel or extra computers with software in schools with 70% disadvantaged students	Regression discontinuity model.: Note that schools in both the treated and not-treated groups already have one computer per 5 students.	Students in treated school spend on average 50 more minutes per week on computers. But no effect on achievement of receiving funding for computers (no effect for extra funds for personnel either)
Barrera-Osorio and Linden (2009)	Columbia Computadoes para Educar program to provide refurbished computers to schools; teacher training for schools that get computers	Program intended to increased number of computers in schools and focuses on using computers for Spanish and other subjects;	Randomized experiment; 97 schools assigned to treatment or control group	Program increased computers in schools but extra computers had *no effect* on math and Spanish achievement scores; computers were not used to teach subjects. They were used to teach computer skill

Machin *et al.* (2005)	UK primary schools	A rule change in the funding of computers for schools that gave more funds to some Local Area Authorities and not others	Instrumental variable model with rule change as the instrument.	*Positive effect* of additional computers on reading, science, not math in primary schools.
Sprietsma (2007)[1]	Brazil	SAEB survey of teachers, principals and students; 1999, 2001 and 2003	Pseudo-panel model, controls family background factors (computer at home) and school resources	*Negative effect* of computer labs on math and reading.
Cristia *et al.* (2011)	Peru	Peruvian government distributed OLPC computers with extensive software programs in poor rural areas. 15-month follow-up	Randomized experiment with classroom observations and surveys in 319 schools in rural areas	*No effect* of OLPC on math or reading test scores

[1] "Sistema de Avaliação do Ensino Básico' administered by the 'Instituto Nacional de Estudos e Pesquisas Educacionais' (In English: National Institute for Educational Studies and Research). The pseudo-panel technique uses several years of repeated cross-section data to group individuals into pseudo-cohorts based on permanent observable characteristics. These cohorts are created on the same criteria in each wave. If e.g. the criterion for being in a same cohort is place of birth then we could create groups of people born in the same municipality. These groups of 'similar' people by construction exist in all years for which we have data. Pseudo-panel consists in using the created pseudo-cohorts in place of individuals in a fixed effects panel estimation. The variation in computer and Internet use across cohorts and over time allows this model to identify the impact of the availability and use of computers on pupils test scores.

use computers and software. So the comparison is between the use of the new software and the software students in the control group use —the comparison is *not* between using CI and not using CI. If CI works we expect this comparison to produce a smaller effect size than if we compared students using CI to students not using it.

Imagine a study in which students in the same classroom are randomly assigned to use CI (the experimental groups) or not to use CI (the control group). Students in the control group can easily interact with students in the experimental group and may in fact even be able to sometimes use the computers and software used by the experimental group. If this interaction results in members of the control group gaining from the experiences of members of the experimental, there is what is known as a positive "spillover." This type of positive spillover is likely to cause researchers to under-estimate the benefits of CI. Spillovers are less likely when the treatment and control groups are in different schools or otherwise in locations that make interaction difficult.

Because so many individual studies of CI have been done, researchers have conducted many meta-analyses of the studies. Meta-analyses are useful for summarizing a large number of studies but they also can obscure as much as they illuminate. Almost all the meta-analyses of computer instruction give equal weight to studies that include different populations such as advantaged and disadvantaged students. This implies the same expected effect size for all populations. The meta-analyses also include studies with different comparisons groups. For example, in some studies the comparison group uses no computer software and in others the comparison group can use software including the software being evaluated. The meta-analyses also give equal weight to studies in which spillovers are possible and those in which spillovers are very unlikely. Because there are so few RCT studies the meta-analyses give equal weight to studies with a variety of research designs.

In research on CI the specific intervention is a computer software program intended to teach specific skills. But different packages are intended to do different things. For example, some software packages are intended to teach accelerated math and some are intended to teach remedial math, some software is intended to teach algebra and some is intended to teach basic addition. Differences in effect sizes may reflect differences in how amenable different skills are to computer instruction.

When researchers select studies to include in a meta-analysis they usually define criteria for inclusion. The conclusion of a meta-analysis depends on the criteria used to select studies. The earliest meta-analyses included almost all studies. Later meta-analyses include only studies that lasted for defined periods and that included a comparison group. Some included other criteria and some consider only software for a specific purpose such as reading or mathematics. Nonetheless, all of the meta-analyses include studies that differ in methods, implementation, and the product being studied. Therefore, differences in effect sizes from different studies could mean that software packages differ in their effectiveness, that some skills are more amenable to computer instruction than others, or that the differences in study design produce different effects. Nonetheless, these meta-analyses are a useful starting point for summarizing the research on CI.

In the past two decades most research in the United States has shown that use of CI in reading and mathematics improves the test scores of children in primary and secondary school. For example, Murphy *et al.* (2001) found that in 31 studies conducted between 1993 and 2000 use of CI increased reading test scores by an average of .35 standard deviations and mathematics test scores by an average of .45 standard deviations. Other early reviews and meta-analyses in the United States (e.g. National Center for Educational Statistics 2001a and 2001b, Kulik 2003, Cox *et al*. 2003, Waxman *et al.* 2003) all found positive effects on test scores. However, many early estimates of CI on achievement are of limited value because the research did not take endogeneity issues into account and therefore could not establish the causal relationship between computer use and achievement.

Recent meta-analyses that have more rigorous criteria for including studies also find positive effect sizes for the use of computers for instruction primarily in the United States and primarily with disadvantaged populations. These include Cheung and Slavin (2011a and 2011b), Li and Ma (2010), Rakes, Valentine, McGatha, and Ronau (2010) Slavin and Lake (2008), and Slavin, Lake, and Groff (2009). In 7 meta-analyses conducted between 1991 and 2003 that evaluated the use of educational technology intended to increase reading achievement the average effect size ranged from .12 to .43 (Cheung and Slavin 2011a). In 21 meta-analyses including research conducted between 1960 and 2010 on the use of educational technology intended to improve mathematics achievement the average effect size ranged from .10 to .62 with an average weighted effect size of .31 (Cheung and Slavin 2011b). In 11 of these meta-analyses the effect size was greater than 0.30 and in 5 the effect size was less than 0.20.

Cheung and Slavin (2011a) include 64 relatively high-quality studies of CI programs intended to increase literacy among kindergarten and primary school children. The evaluations took place between 1983 and 2010 (all in the United States except for one in Finland and two in Australia)[14]. In the vast majority of studies participating students were from disadvantaged families and schools. As Table 2 shows, all but 10 of these evaluations produced positive effect sizes. The negative effect sizes were generally not statistically significant at conventional levels and their unweighted average effect size was -0.100. Most studies estimated positive effect sizes less than 0.20. The weighted average effect size was 0.170 for the 64 studies. However, this average overlooks some important distinctions.

Of these the 64 evaluations 26 took place before 2000. Evidence about whether effect sizes have changed over time is equivocal (Kulik and Kulik 1987, Fletcher-Finn and Gravatt 1995, Liao 1998, Christmann and Badgett 2003). Cheung and Slavin (2011a) find no statistically significant difference between effect sizes found in early studies compared to more recent studies but that could be because the studies themselves have changed. For example, if more control groups are using CI software we expect smaller effect sizes.

Of the 64 evaluations, only 14 use RCT methods with a large sample (more than 250 students). All of these 14 have been done since 2000. All the effect sizes from these studies are positive and most were less than 0.20. However, of these 14 RTC studies 6 were done as part of a large study sponsored by the United States Department of Education (Campuzano *et al*. 2009, Dynarski *et al*. 2009 and 2007) at the request of Congress. These evaluations are typical of much of the research on the efficacy of computer software and highlight a problem noted above. The study evaluated the use of 16 educational software products for math and

[14] Cheung and Slavin (2011a and b) also include studies assessing the effect of computer managed learning systems. I omit these from this summary of their work. Cheung and Slavin (2011a) also include a few studies evaluating "innovative technology applications." I include these in the summary of the meta-analysis because most of these could be considered versions of CI.

TABLE N° 2: SUMMARY OF STUDIES OF COMPUTER-ASSISTED INSTRUCTION

	Primary school		Secondary school	
	Literacy	Math	Literacy	Math
Total number of studies	64	39	17	24
With ES > .30	8	11	7	4
With ES .20-.29	13	6	1	5
With ES < .20	33	16	8	10
With negative ES	10	6	1	4
Number of large RTC studies	14	4	0	9
With ES > .30	0	2	0	1
With ES .20-.29	3	0	0	0
With ES < .20	11	2	0	5
With negative ES	0	0	0	3

Source: Cheung and Slavin 2011a and 2011b.

reading in first, fourth and sixth grade. In each school that was selected to participate, teachers who volunteered in each grade were randomly assigned to use the study product (the treatment group) or not (the control group). The influential report to Congress concluded that there was no increase in test scores from the use of software in the classroom. However, neither school districts nor schools were randomly selected and even though the researchers controlled observed differences between schools, the possibility of unobserved heterogeneity remains. Secondly, control group teachers were able to use other technology products in their classes and they did. About 75 percent of control group teachers reported using at least one technology product in their classroom, and 55 percent of treatment teachers used at least one technology product in addition to the experimental product. Thirdly, the possibility of both positive and negative spillovers between classes in the same schools is great. For example, students can learn from friends in other classes and parents whose children are not in the experimental classes my try to compensate by providing software for their children to use at home. As a consequence of these problems with the research design, it is not clear how credible the effect sizes are. This also highlights one potential difference between studies done many years ago before most students used computers at school and recent studies where the comparison groups will usually be using school computers.

Sometimes the same software is evaluated more than once and when it is the effect sizes are not always the same. For example, in two recent studies of the Waterford Early Reading Program that both used large matched samples, were both done in high poverty neighborhoods and both used the software for 15 minutes daily, the effect size was 0.00 in one study (Paterson *et al*. 2003) and 0.47 in the other (Tracy and Young 2006). This could mean that the matched groups differed or that the implementation differed.

Cheung and Slavin (2011a) divided the studies into two categories of CI. “Supplementary” CI programs provide instruction at students’ assessed levels of need to supplement traditional classroom instruction. “Comprehensive” CI models use computer-assisted instruction along with non-computer activities as students’ core reading approach. Evaluations of comprehensive models produced effect size estimates of 0.28 and supplementary programs produced effects sizes that averaged 0.11. However the evaluations of supplementary programs is dominated by the Department of Education studies described above so it is unclear how much weight to place on these differences.

Turning to CI for kindergarten and primary school mathematics, Table 2 shows that Cheung and Slavin (2011b) included 39 estimates in their meta-analysis. Six of the effect sizes were negative but 11 were greater than .30. The negative effect sizes were generally statistically indistinguishable from zero (the average negative effect size was -0.078). Most effect sizes were less than 0.20. Only 4 of the 39 studies used RCT methods. All of these produced positive results with 2 effect size estimates greater than .30 and 2 less than .20.

Many fewer evaluations of CI have been conducted with secondary school students. Cheung and Slavin (2011a) include 17 estimates of the effect of CI on the reading achievement of secondary school students. Only one of these evaluations estimated a negative effect size and 7 estimated effect sizes greater than .30. None of these studies use RCT methods. Cheung and Slavin (2011b) include 24 estimates of the effect of CI on secondary school students’ math scores. Most of the effect size estimates are less than .20 and of the 9 RTC estimates 6 are from the United States Department of Education study described above.

Table 3 shows five recent studies that use econometric models or RCT to compare students using CI to students not using CI in developing countries. Three of these studies are in India, one is in Brazil and one is in Ecuador. Three of the studies estimate that CI increased test scores (Banerjee *et al.* 2007, Carrillo *et al.* 2010 and Sprietsma 2007). One finds mixed results: He, Linden and MacLeod (2008) found that young students in large classes who used a very simple computer-like machine for instruction had higher test scores than students who used the same curriculum delivered by traditional means. But there were no differences for older children. Linden (2008) found that when CI was substituted for traditional classroom instruction students scored lower in math, but when it was used after school (and therefore students received more math instruction) math scores rose.

Returning to Table 1, Machin *et al.* (2005) was the study that estimated a positive effect of a program that provided more computers to schools. That program was in the United Kingdom where, unlike in most other places, the computers that were purchased were mainly used to deliver CI to students. In primary school for example, in the 1999-2000 school year almost 70 percent of teachers reported "substantial use" of computers for teaching English, and 56 percent reported "substantial use" of computers for math instruction. As early as 2003 92 percent of primary school teachers reported using computers regularly for teaching math.

Although studies occasionally estimate small negative effects from using CI, the vast majority of studies estimate positive effects. We can broadly and tentatively conclude that at least in the United States, using CI in classrooms is likely to increase test scores in mathematics and reading although the heterogeneity of effect sizes across studies makes it impossible to have a lot of confidence in how much improvement to expect. A best guess from recent meta-analyses and from international studies suggests that a conservative guess would an effect size of about .20 for reading and perhaps slightly higher for mathematics. The majority of the evidence on the effect of CI is from the United States or other developed countries. As noted above CI is likely to produce bigger achievement gains when teachers are less skilled, class size is large, students are heterogeneous of under other circumstances that decrease the quality of the traditional classroom experience. These conditions are more likely to occur in less developed countries.

For policy makers it is not enough to know whether access to or use of computers improves educational outcomes. Policy makers

TABLE 3: EXPERIMENTAL EVALUATIONS OF COMPUTER INSTRUCTION ON TEST SCORES

Author (Year)	Location and program	Model and sample notes	Results
Banerjee *et al*. (2007)	India: various computer games; 2 hours of shared computer use per week; grade 4 students; 2 years	Randomized experiment, 111 schools	Computer games raised math scores in India by .33 SD in first year and .47 SD in second (some fade out a year after the end of the program)
Sprietsma (2007)	Brazil: Teacher responses to survey about their use of computers for lessons	SAEB survey of teachers, principals and students; 1999, 2001 and 2003; Pseudo-panel model, controls family background factors (computer at home),s school resources	Positive effect of teacher using computer as a pedagogical tool of .184 SD (Portuguese) and .089 SD (Math) test scores.
Carrillo, Onofa and Ponce (2010)	Guayaquil, Ecuador: Mas Tecnolgia program to provide infrastructure and at least 4 computers to schools with software for language and math	4 treatment and 4 control schools	Positive effect of the program on math scores (.30 to .38 SD depending on the model); statistically insign, difference for language
Linden (2008)	Gujarat, India; A computer-assisted version of the Gyan Shala educational system (a high-quality teaching method).	Random assignment to CI program or regular Gyan Shala program. Program implemented as a substitute for classroom experience (no change in	When used as a substitute students learned .57 SD less; as a compliment student scores increased .28 SD. Largest gains for

		instructional time) and after school (more total instructional time); 60 schools in 4 locations, half control grades 2 and 3	poorly performing students (.40 SD) and older students (.69 SD)
He, Linden and MacLeod (2008)	Maharashtra, India; English language curriculum delivered through specially tailored flash cards or through specially designed software and booklets used with a uniquely designed electronic machine (called a PicTalk machine).	Random assignment to control, machine and traditional, traditional and machine groups; About 240 schools	Both computer and traditional delivery of curriculum increase English scores by about .30 SD.; greater effects for PicTalk usage in grades 1-2 but not in higher grades; PicTalk delivery had greater effects than traditional delivery in larger classes; PicTalk delivery may have greater effects for more disadvantaged students.

must assess the benefits of CI against the benefits of other education reforms that cost about the same amount. A cost-benefit analysis of CI is beyond the scope of this paper, but the effect sizes in Table 3 and the effect sizes from the studies included in recent meta-analyses suggest that CI could be as effective at improving math and reading skills as many other reforms currently on the policy agenda in most countries. To put the effect sizes in perspective, the estimated effect size from reducing class size by 10 students is around .10 in studies that estimate a positive effect (e.g. Urquiola 2000, Fredriksson *et al.* 2001, Krueger 1999). The effect size of increasing the number of instructional days by 10 is between .15 (Lavy 2010) and .20 (Marcotte and Hansen 2010).[15] Reducing class size is much more expensive than providing CI and may be more expensive than increasing the number of instructional days in the school year. Available evidence shows that most teacher and student incentive programs, school reorganization efforts, and most forms of teacher pre-service and in-service training produce changes in test scores that are smaller than the average effect sizes from using CI. Some of these may be less expensive that instituting computer instruction in schools but some are likely to be much more expensive.

Virtual schools. The United States Department of Education recently published the most comprehensive summary of research available on virtual schooling in the United States. This researcher is instructive about the state of research on technology in schools. Their search for research articles on the efficacy of virtual schooling turned up 1,132 relevant research abstracts. They screened these to find the studies that: (a) contrasted an online to a face-to-face learning environment, (b) measured student learning outcomes, (c) used a rigorous research design, and (d) provided adequate information to calculate an effect size. Of those 1,132 studies they began with, only 50 met these criteria. Only 5 of these studies produced estimates for students in primary or secondary school. Overall the meta-analysis suggested that students in virtual learning environments performed modestly better than students in face-to-face instruction. The effect sizes for primary and secondary

[15] Note that some studies estimate a negative or no effect from either reducing class size (e.g. Leuven *et al*. 2008, Duflo *et al.* 2009, Hanushek 1999, Jepsen and Rivken 2002 and Hoxby 2000) or from increasing instructional time (e.g. Baker *et al.* 2004).

school students were all positive there were too few to result in a statistically significant effect size.

It is safe to say that we simply do not know the effect of virtual schools or virtual courses on educational outcomes of primary or secondary students. This is surprising and troubling given the rapid growth in the number of virtual schools and virtual courses taken by students at least in the United States.

III. Conclusions

Computers and their use have become an increasingly common in schools around the world. It has become common for students to have computers at home even in developing countries and commonly used software has become more user-friendly. This has diminished the need for schools to spend much time teaching basic computer. But within countries the digital divide remains and the need for schools or other public places to provide access to computers for disadvantaged students remains especially in less rich countries

While access to computers is a necessary condition for their use, access does not guarantee that students will use the computers, and getting students to use computers does not guarantee that they will use them in ways that improve their cognitive achievement. Most students report that they do not use school computers at all in core subjects. When students do use computers in school it is generally to search the Internet, work on group projects, or to use the Internet to do homework. Research shows that programs that increase the number of computers in schools have had little effect on students' test scores. This implies that these uses of computers do not increase achievement. However, a growing body of research does suggest that when computers are used to provide instruction test scores in reading and math increase. However, CI is not very common in most countries and even in the United States CI is rarely routinely used in schools.

Although the use of CI has been studied more than other potential uses of computers in schools, even that research leaves much to be desired. The majority of research has not used RCT even though it is clearly the best way to evaluate the use of computers and other education policies and programs. In fact not using RCT to evaluate important policies and programs can have disastrous consequences.

One example comes from the medical area. Hormone replacement therapy (HRT) was for many years encouraged for post-menopausal women who had survived breast cancer on the basis of encouraging observational evidence. Eventually HRT was subject to a randomized trial. The trial had to be stopped early because HRT not only had no beneficial effects it actually increased the risk of cancer reoccurrence three-fold (Hsia *et al*., 2006, Angrist and Pischke, 2009). Random control trial experiments need not be especially expensive and the cost of a well-designed RCT is far out-weighed by the cost saving from avoiding implementing programs that do not work. RCT can be used not only to determine whether programs work but also how best to implement programs already implemented.

A limitation of existing research in education policy in all countries is the lack of attention to benefit-cost analysis, which makes it difficult for policymakers to focus resources on programs that will maximize the social good that can be accomplished for a given level of funding. As noted above several educational interventions may be able to produce effect sizes on the order of .20 but the cost of these interventions varies greatly. CI may be relatively inexpensive compared to other interventions and the cost of computer-based instruction generally declines over time as technology becomes less expensive while the cost of many of these other interventions can increase.

It is important to understand not only average effects of educational interventions but also to understand whether there are differential effects for disadvantaged and advantaged children where advantage can be defined by family background or by cognitive ability. A program that increases average performance mainly by increasing the performance of advantaged students will increase inequality of performance. A program that increases test scores for disadvantaged students without hurting scores for advantaged students will both increase mean scores and decrease inequality in scores. The vast majority of research on CI has been on disadvantaged populations so we have little evidence to guide educators or policy-makers about this issue.

Chile, like most other countries, has already made a large investment in getting computers and the Internet to school children. It is now time for educators and policy-makers in all countries to turn their attention to how make that investment pay off. Converting the time that students now spend on computers into more productive time using CI would be a good start. However, educators and policy makers should demand that software be evaluated using best-practice RCT methods. Information on the cost and effectiveness of specific educational software packages should be made widely available so that teachers and principals can choose the most cost-effective programs to assure their students' achievement gains. Because so much is at stake when choosing educational practices, policy-makers should consider creating barriers to schools using unevaluated software products. This would provide an incentive for software developers to pay for independent evaluations of their products and to price their products in a way to achieve a reasonable cost-effectiveness ratio. In the end this would benefit schools children.

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