Success, Failure or no Significant Difference: Charting a Course for Successful Educational Technology Integration

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***Abstract*—The question of whether computers have positively or negatively impacted student learning is still hotly contested in educational technology circles, particularly in the area of international development, by proponents and critics of technology in education. Overall, research offers conflicting answers to this question. However, the abundant research on effective school change and innovation implementation points to practices which those who promote technology in schools should tap. This paper outlines the long-term structural conditions that can lead to the deep change technology initiatives seek to promote.**

***Index Terms*—Benefits and weaknesses of ICT in education, educational technology debate, ICT in education**

I. INTRODUCTION

Have computers positively or negatively impacted student learning? Responses to such a broad and binary question often serve as sort of a Rorschach test of respondents' beliefs about the potential and actual benefits of technology as a reform tool; the responsibilities of schools and teachers vis-à-vis technology use and adaptation; and organizational and human change processes.

The rhetoric around educational technology, particularly in non-industrialized nations, but in industrialized country contexts as well, is energetic and robust—as the most cursory reading of blogs and discussion boards on the subject will attest. Broadly and dichotomously, the two camps may be defined as *techno-dissenters* who believe the impact of technology on education, particularly on teaching and learning, has been "oversold" [1] and unproven. Such techno-dissenters may be former technology enthusiasts who have been chastened by a lack of unequivocal longitudinal research demonstrating causality between technology use and student achievement and who are thus skeptical of reputed benefits. Among the ranks of such detractors are those who rail against what they see as the threat of "technopoly" [2]—an overemphasis on rationalization, quantification and efficiency that belies arguments for educational technology use and overly technocratic prescriptions for what are often human and structural maladies in schools. The suggested remedies of techno-dissenters range broadly from proposing a moratorium on or cuts in technology spending in schools, to greater reflection and examination about technology use in schools, to a cooling of the rhetoric around technology's learning potential.

The second camp, which I term *techno-enthusiasts*, sees technology as essential to increasing modernization and efficiency in schools. They may regard technology as tools of educational reform, in particular compensating for (or even eliminating) poor teachers and teaching. They may view technology as a catalyst for propelling students toward 21st century learning [3]. Many techno-enthusiasts see computers as tools for student engagement, indirectly resulting in learning gains and directly resulting in such qualities as increased confidence and self-efficacy. A small but significant group consists of educational technology utopians who see computers revolutionizing the educational paradigm. Though many acknowledge the dearth of consistent, large-scale research showing a causal relationship between technology and student learning, they indict the poverty or poor quality of human and structural supports versus limitations with the technology itself.

In fairness to both "camps," each argument is more nuanced than reported here. Further, debates around classroom computers are often more multipolar than bipolar. Nonetheless, arguments can be distilled to the same competing sentiments toward computers as student learning tools. Though the temptation is to ask, *Which camp is right?* it may be more useful to examine the substance of issues raised by each side. Techno-enthusiasts are correct in stating that the issues that plague "schooling" are human and organizational and not derived from technology *per se*. On the other hand, as techno-dissenters rightly note, there are abundant examples of failed technology initiatives and school computer use that diverts from, rather than enhances, student learning.

II. COMMON GROUND

Yet both sides are closer to agreement than appears at first blush. Both camps agree that the issues that beset computers as learning tools have little to do with technology *per se*—tools themselves are but artifacts of human attitudes, values and needs. Both techno-dissenters and techno-enthusiasts, through their attack on computers' failure to cure what ails schools and their indictment of school environments that thwart the vast potential of technology, respectively, essentially point to the same issue—the failure of educational technology initiatives are structural and human in nature and thus any curative measures must address these human and organizational issues.

Accordingly, a preponderance of research evidence suggests that under certain conditions, technology is correlated with improved student academic performance across a range of content areas [4]. This is where the arguments of techno-dissenters and techno-enthusiasts can fuse. Rather than focusing on technology solutions, we must turn these conditions into the "right" conditions.

This article uses the competing camps of techno-dissenters and techno-enthusiasts as a launch pad to explore conflicting research around technology's impact on student learning. It begins by summarizing the essential link between new notions of learning and teaching and their nexus with technology (I use "technology" and "computers" synonymously in this article). I argue that where we've seen teachers use technology to help students learn in ways that not only support, but make possible learning that would otherwise be impossible, it is because nations or districts or schools have cultivated the far more difficult human and structural infrastructure necessary for this success. I conclude by proposing a number of requisite scaffolds or conditions, primarily for non-industrialized country contexts, necessary for the convergence of technology and learning to truly occur.

III. TEACHING, LEARNING AND TECHNOLOGY: AN OVERVIEW

We have made great strides in the past several decades in understanding how learning occurs. We know that learning is not an isolated or static process. As we interact with the world around us, and the infinite variety of images, ideas, information, and other stimuli that comprise our world, we are constantly constructing, revising, and reconstructing our knowledge and beliefs to create a new framework of understanding. Knowledge then is constantly under construction—a dynamic, evolutionary, developmental process.

We know too that learning is influenced by our level of biological and psychological development. As the writings of Jean Piaget [5] assert, children think and reason differently at various periods in their lives, passing through a series of stages in their cognitive formation—from the *sensorimotor stage*, during which the child gains motor control, through to the *formal operational stage*, where the child begins to reason logically and systematically.

And we know that learning is oftentimes fraught with tension and conflict. If new information matches our existing understanding, we can easily assimilate it. However, if new information does not match our existing framework—or threatens our existing corpus of knowledge—we must accommodate it, either by forming new understandings, or re-evaluating our prior beliefs and reconstructing our prior theories, or reject that new information. This continuous struggle between pieces of varying and oftentimes conflicting information—this *dialectic* of learning— occurs constantly, sometimes consciously, or more often, unconsciously, and contributes to our overall construction of knowledge. Without this disequilibrium, the student's belief system is not challenged and the potential for greater intellectual growth is stifled. Learning then is rarely a final product. More often it is a constant, evolutionary, and sometimes revolutionary, process.

The idea of learning as a developmental process has also been firmly established in a number of educational systems across the globe through learning "taxonomies." The most well-known—Bloom's Taxonomy—identified six levels within the cognitive domain, from simple recall or recognition of facts and comprehension of these facts at the lowest level, through increasingly more complex and abstract mental levels—or "higher-order thinking"— such as application, analysis, synthesis, and evaluation [6].

These three conditions for knowledge construction (and these are by no means the only three)—*learning as a product of interaction with rich stimuli; learning as a continual, developmental, evolutionary process; and the dialectic of learning* (knowledge and concepts constructed through the interplay of various factors) have spawned a new focus on instruction and on pedagogical approaches. The traditional transmission model (e.g., lecture/short answer format), with its emphasis on quantity, coverage and product creation has yielded, or is at least losing ground, to learner-centered approaches with their focus on learning as a *process* that must be examined and understood.

Thus, in many classrooms across the globe we have seen increased attention on new conceptual structures and understanding of complex and often conflicting information. Mindful of the new body of knowledge on learning, we notice greater efforts to purposefully utilize *learner-centered* pedagogy—an instructional approach in which students explore, manipulate, question, and discover answers for themselves. We observe attempts to create activities that are developmentally appropriate, yet challenging enough to allow for a certain level of frustration on the part of the learner. In short, to use Bloom's taxonomy once again, we see attempted convergence between instruction, curriculum, and tools in the promotion of higher order learning.

IV. TECHNOLOGY AND STUDENT LEARNING

Since learning occurs by interaction with rich stimuli, is a developmental process, and generates new knowledge that challenges, adds to, or deepens the learner's existing framework of knowledge, computer technology would appear to be a good fit with the above paradigm. When used appropriately, technology can become a "mind tool," functioning, in Jonassen's words [7] as an intellectual partner with the learner to engage and facilitate critical thinking and higher-order thinking.

We have embraced technology's potential to help students scale the levels of intellectual development. Industrialized nations have invested millions of dollars to make such "mind tools" accessible to most, if not all, learners. Donors, foundations and government agencies in non-industrialized countries have provided computer labs, teacher training and in some cases, "one laptop per child" to extend the purported learning benefits of technology to the world's poorest teachers and students. This move to provide access to all teachers and learners rests on the belief and hope that computer technology, by its very multichannel and interactive nature, is an *ipso facto* learning tool, and that by employing computers in a manner consistent with what we know about best teaching and learning practices, students will be more likely to attain such higher order thinking, 21st century learning or simply just demonstrate learning gains.

V. COMPUTERS AND LEARNING: THE GOOD, THE BAD, THE CONTRADICTORY AND THE INCONCLUSIVE

Yet the outcomes of this long hoped-for convergence of technology and learning are confounding. Hypotheses supporting or refuting the link between technology and learning remain inconclusive and contradictory as the following selection of well-known and large-scale research on technology and learning attest.

A. Positive Benefits

Research increasingly notes the relationship between student computer use and increased academic performance (primarily gauged through national or international examinations). A quick encapsulation of some cross-study findings are noted here:

- **Benefits of technology on increased math and science content knowledge:** One of the most well-known meta-analyses on the connection between computers and student learning is that of Kulik [8] who noted that students who used computer tutorials in mathematics, natural science, or social science scored significantly higher in these subjects compared to traditional approaches—equivalent to an increase from 50th to 72nd percentile in test scores. Similar findings suggesting the link between technology use and improved math and science scores can be found in international studies [9] [10]. Kulik's meta-analysis also revealed that students who used simulation software in science also scored higher, equivalent to a jump from 50th to 66th percentile. Consistent with Kulik's meta-analysis, Integrated Learning Systems (ILS), which usually rely heavily on tutorial instruction, have been producing positive results in mathematics programs for decades. Computer tutorials in natural and social science classes also have had an almost uniformly positive record of effectiveness in the1970s, 1980s, and 1990s [11].

- **Benefits of technology on students' science scores in PISA:** The Organization for Economic Co-operation and Development (OECD) has for the past several years tracked the link between student computer use and student scores on its Programme for International Student Assessment (PISA). Analysis of 2006 student science scores by the OECD suggests that student performance in science is positively related to length of computer use. Students from OECD countries who have used computers for more than five years, and are therefore more familiar with computers, score at the middle and higher end of Level 3 in science in PISA versus students who have been using computers for less than two years, who score at the middle or low end of level 2. The difference between these two scores is 90 points or more one entire level of proficiency [12]. However, the report notes that greater computer use is tied to higher socioeconomic status which in turn is linked to higher academic achievement.

- **Improved writing:** US students who used word processors or otherwise used computers for writing scored higher on measures of writing skill, equivalent to a rise from the 50th to 62nd percentile [13]. Also in the United States, Russell & Plati [14] examined 4th and 8th grade students who had access to digital writing tools such as a laptop, an E-Mate or an Alpha Smart. These students—even when they took the test using paper and pencil—did better on state writing tests than their peers who had access to no such digital tools. The study's authors concluded that the mode of test administration is important—open-ended writing prompts that require students to generate responses using paper and pencil underestimate the achievement of 4th and 8th grade students used to writing with computers [15]. Consistent with these findings is a body of research since the 1980s demonstrating a consistent link between word processing and improved writing scores [16].

- **Links between "e-maturity" and student performance scores:** The *British Educational Communications and Technology Agency (*BECTA) reported that schools with good ICT resources, such as high-speed broadband access and interactive whiteboards, achieve better results in national tests taken at age 16. Interactive whiteboards, in particular, appear to result in improved test performance for low-achieving students particularly in writing, math and science [17].

B. Negative Results

There are also a number of well-known studies that demonstrate a negative link between student computer use and learning.

- **Higher scores for students in face-to-face versus online learning situations:** One study [18] compared student scores in face-to-face and online economics courses taught at three different institutions. After taking into account selection bias and differences in student characteristics, they reported that the average scores were almost 15 points higher for the face-to-face format than for the online format.

- **Higher scores for non-users of technology:** An Israel study [19] analyzed the effects of a large-scale computerization policy in elementary and middle schools. Treatment schools received technology. Control schools did not. The researchers found evidence that increased educational use of computers did not raise test scores. Rather, they found a negative and significant relationship between the program-induced use of computers and the 4th grade maths scores.

- **Higher levels of student achievement for students lacking access to computers:** Fuchs & Wößmann's oft-cited study shows a positive correlation between student academic achievement and computer availability both at home and at school. However, once researchers controlled extensively for family background and school characteristics, the relationship became negative for home computers and insignificant for school computers. The authors concluded that "mere availability of computers at home seems to distract students from effective learning" [20].

C. Contradictory results

Increasingly, as evaluations become more rigorous, there appears to be a good deal of contradictory evidence about technology's impact on student learning. Much of this contradiction is grounded in the nature and size of the studies. Further, the divergence in results often breaks along lines of socioeconomic, gender, student achievement, and ethnic differences.

- **Different achievement results with different populations:** A 2010 OECD study finds that computers "amplify" the differential between richer and poorer science students in Finland, Ireland, Spain and Switzerland while also ameliorating this gap among rich and poor science students in Canada, the Czech Republic, New Zealand, Poland and the Slovak Republic [21].

- **Lack of consensus around technology's benefits in science achievement:** The OECD's 2010 report on student computer use and its relationship to PISA scores contains several contrasting statements. In one part of the report, authors note that computers are "not necessarily more beneficial for students in subject-based assessments" [22] and "Higher performance in science is related to lower educational use of computers" [23]. These statements are in direct contrast to other parts of the report which link computers to positive attitudes and performance in science [24].
- **Conflicting results about the same types of technology interventions:** Some studies of online instruction and its impact on student learning show no consensus on the impact of the same technology intervention. For instance, in the US, Cavanaugh found "equivalence" between face-to-face and online learning [25]; while Shachar & Neumann found "significant positive effects" for online learning over face-to-face instruction [26]. In contrast, Ungerleider & Burns noted "no significant difference" between the two [27].

D. *No difference or inconclusive evidence*

Particularly with newer technologies and newer innovations, such as virtual schools or tablets, there is often a lack of what the US Department of Education's *What Works Clearinghouse* calls "acceptable" standards of evidence.

- **No significant difference:** Another OECD report shows that computer use in school shows no significant difference in students' scores on the PISA. Austria is the only country where computer use at school had a larger effect on science scores than at home (3 points) [28].
- **Correlation but not causation:** Britain's ImpaCT2 study of over 2000 Key Stage 2 and 3 pupils from 1999-2002 showed that ICT had a positive relationship to students' learning of mathematical skills linked to the amount and type of use of ICT in the mathematics curriculum. High users of ICT at KS3 outperformed, on average, low users of ICT in mathematics, but differences at KS4 were slight. However, this aspect of the research looked only at correlation and not causation [29].
- **Conflation of computers and socioeconomic status:** Computer use is often used as a proxy for individual household wealth. Researchers [30] [31] point to wealth as a greater determinant of student academic performance than access to and use of computers. Where computers have been shown to increase student academic performance, the use of computers often links back to higher socio-economic status.

Contradictory results can be found in any domain, but for education, which is primarily publicly funded, and for technology, upon which so much unfulfilled or dashed hopes have been placed, such cross-currents fuel techno-dissenters' thesis—educational technology is a disappointment and waste of scarce resources. Further, such contradictory results beg the question—why isn't there more certainty around the relationship between technology and learning? Why after three decades of computers in schools, two decades of the Internet in schools, and a decade after uptake of mobile learning devices for education do we not have greater clarity about technology's impact on student learning?

VI. TECHNOLOGY IN SCHOOLS: THE "RIGHT" CONDITIONS

The concerns of techno-dissenters are not simply academic or philosophical but financial and educational. Money is a finite resource. Governments and donors have expended enormous amounts of money for technology in the hope that computers can reform schools in ways that other initiatives have been unable to and many nations are either poised or considering huge investments in educational technologies as part of economic planning. There is evidence [32] that such spending places greater financial burdens on poorer and middle income countries than on rich ones. Similarly, the education sector has a long history of investing in innovations that are often discredited. And, as techno-dissenters imply, a great deal of fetishism characterizes any use of technology in schools. But again the two sides' arguments can be reconciled on a practical level. As both camps would agree, donors, ministries and schools have more often than not neglected to establish the conceptual, organizational, and instructional and evaluator framework—the "right" conditions—in which teachers and students can succeed so that the rich, complex and intricate kinds of learning with technology, described earlier can begin to form and flourish.

A. *Policy and Programmatic Changes*

Teachers, not technology, are essential to student learning—and teachers do not operate within a vacuum. Rather, they often function within multi-layered, matryoshka-like educational systems. This larger system includes policies and the beliefs such policies implicitly espouse about how children and adults best learn and work; associated practices to disseminate such policies; the establishment of curricular, assessment and evaluation systems to implement such practices; attitudes about the professionalism and capacity of teachers and principals to implement such practices; and beliefs about how technology should be used, for what purposes and by whom. This is the superstructure within which educational technology initiatives must operate, with which they must conform, and against which they must contend. As the title of Larry Cuban's book, *Computers Meet Classroom; Classroom Wins* adumbrates, the organizational *status quo* can often neuter even the most dynamic and hopeful of innovations.

If, as techno-enthusiasts, hope, and techno-dissenters lament, computers have any hope of becoming tools of learning, the larger educational landscape must be cultivated or more accurately, reverse engineered, to allow teachers and students to use technology tools as efficiently as possible. The remainder of this article outlines what this re-engineering should involve:

Establish a Vision of How Technology Should Be Used: Policymakers and educational designers must have a vision of what classroom teaching and learning will look like as a result of technology investment and provision. This vision building is often the most important—and most overlooked—part of planning for computers in schools. Failure to create, articulate and accommodate a common vision predictably results in technology projects that meander or sputter toward an unanticipated and unwelcome end. A well-defined and clearly articulated vision developed by all actors in the education system provides coherence to the project, serving as the organizing framework within which all goals, actions, infrastructure, and activities can be developed, and results evaluated. The process of creating a common vision can also help to build engagement and commitment among education stakeholders [33].

Develop a Shared Language about Teaching, Learning and Technology: Discussions about optimal practices around classroom technology often resemble Shaw's wry observation about the English and Americans divided by a common language. Terms such as "Information and Communications Technologies" have different meanings to different stakeholders (They even have different meanings to the same stakeholders.). Essential instructional constructs, such as "learner-centered instruction," are often incompletely understood by policymakers and teachers. As such there is often a divergence of understanding, and even more critically, incongruent philosophies of implementation among actors within the educational system. As a result, profoundly central requisites for effective technology use, concepts like "integration" or "higher-order thinking," become clichés and their implementation uneven or superficial [34].

Part of establishing a common vision around how teachers can teach with technology to promote the kind of student learning discussed earlier includes the development of a common language, with shared definitions, standards, levels and outcomes. One advantage of this is that by thinking through what terminology means, we can begin to think in terms of levels of use and desired outcomes.

Align curriculum, instruction, technology and assessment: Content, curriculum, instruction and assessment cumulatively and inextricably drive teacher practice. Of these, the assessment system holds the greatest influence since it determines instruction—regulating what, and most importantly how, concepts get taught. As noted earlier in this paper, there is sufficient research suggesting that technology yields the greatest learning benefits when it is used in learner-centered ways [35] [36] [37] [38]. There is also abundant research documenting that the skills that educationally sound uses of computers can promote cannot be adequately measured by most national examinations [39].

National examination systems within which teachers—particularly middle and secondary school teachers—operate result in the implausibility, if not the impossibility, of utilizing technology as part of learner-centered instruction, higher-order thinking or project-based learning. Such instructional approaches are time intensive and written examinations may not measure the knowledge and skills promoted by such approaches. But unless these core components—how the curriculum is structured; what content is taught; what level of learning (memorization vs. analysis of content) is cultivated; and what constitutes "learning" and how it is assessed, computer technology will continue be used in the most perfunctory of ways—high-tech tools that support low-level learning.

To support the types of instructional changes promoted by learner-centered technology use, policy makers and implementers must reform all four of these components purposefully and simultaneously. To focus on one to the exclusion of the others dilutes the possibility of meaningful use of technology. It creates the sort of practice-based tensions which teachers often feel when asked to use technology in higher-order ways within a curriculum and examination system that focuses on lower-order skills.

Create teacher standards that promote the adoption of learner-centered instructional practices supported by technology: In many countries, there is often no compelling reason for teachers to change their instructional practice and/or use computers. On the student-performance side, as noted above, the curriculum, content, and most important, the assessment system, overwhelmingly favor traditional, teacher-centered, fact-based, rote instruction. On the teacher-performance side, many nations, states or provinces often have no standards against which to assess teachers' instructional practice and use of computers as part of classroom instruction; no indicators that evaluate the impacts of the adoption of new techniques and tools; no mechanisms through which to tailor ongoing professional development inputs; and no coherent framework for the provision of mentoring and support to teachers grappling with the crucible of change prompted by new pedagogy (learner-centered instruction), new tools (computers) and high expectations. Oftentimes, teachers who change their practice do so of their own volition and personal force of will. They are but a small portion of the overall teaching force (according to change literature, about 2.5 percent of any population [40]) and not surprisingly, the persistence of those changes typically attenuates over time.

Focus on teacher professional development and support capacity: Many teachers in poor nations and in underserved regions have weak content and instructional skills. Yet, implicitly, the fantasy that learning how to use a computer will somehow transform poor teachers into highly skilled practitioners persists. For such teachers, computers do not improve their instructional skills; they often exacerbate them by shifting the teacher's efforts from instruction and classroom management to technology operations and by diverting the attention of the teacher education system from improving teachers' instructional and content skills to teaching teachers how to use computers.

Educational research is unambiguous on this point—student learning is inextricably linked to teacher quality. Teachers' preparation in content and pedagogy are associated with instructional practices and quality, which in turn influence student achievement [41] [42] [43]. Therefore any school-based technology initiative, particularly in contexts where teachers have received inadequate in-service formation, must focus on improving teachers' content, instructional and assessment skills and help teachers identify how computers can or cannot support these domains.

Educational research is similarly unambiguous on quality teacher professional development. It must be long-term, intensive, ongoing, linked to actual teacher classroom practice and is far more effective if school-based versus centralized [44] [45]. Most critically, teacher professional development must include an extensive ongoing support system. "Support" includes not simply technical support (like electricity, adequate bandwidth and functioning computers) but administrative support (school principals and education inspectors who understand the new instructional methods necessary so teachers can adequately integrate computers into content areas); material support (paper, chairs, teaching and learning materials); time; emotional support by school leaders and above all, ongoing and consistent instructional support from a knowledgeable and caring follow-up person, head teacher, coach or mentor). This is often the most expensive portion of school-based technology investments but without this, the returns on investment in educational technology are negligible [46] [47].

Secure principal involvement: Leadership is a critical ingredient in school-based change. School leaders/ principals establish the school climate; make decisions about the values and "infrastructure" of the school; and can determine when and by whom computers are used in schools. The connection between supportive and facilitative leadership and implementation of innovations is well established in educational research [48].

Just as teachers need to shift from being purveyors of information to facilitators of learning in a new educational paradigm, principals to must move from being purely administrators to becoming instructional leaders. This is a role for which most principals are ill-prepared and ill-equipped. Any technology initiative focused on demonstrating tangible improvements in classroom practice must include principals – both in the same types of professional development teachers undergo and in their own professional development, i.e., focused on the induction and support required to institutionalize change at the school-level. This way, the principal is able to experience and understand the new practices, and is also equipped with additional skills to carry out, support, monitor and evaluate change. This can ensure a greater degree of alignment between the objectives of the technology initiative and the principal's goals and priorities.

Restructure technology evaluations: There are presently a number of weaknesses with the current system of evaluating educational technology initiatives. First, program evaluations are notoriously tricky affairs, particularly in education and particularly in contexts where people may be ill acquainted with evaluations. As Dede *et al.* note, it is exceedingly difficult to assess the impact of any innovation within school settings:

Assessing "impact" (the degree of transformation in practice) and "reach" (the number of teachers and organizations influenced) are important, but complicated. Often, within the complexity of educational settings, where multiple school change and … initiatives may be underway simultaneously and students move from teacher to teacher, it can be difficult to isolate and attribute the contribution of one … program on a teacher's development, and even more difficult to gauge the effect … on student achievement or understanding [49]

Next, because of these difficulties, many government and aid agencies often ask for evaluations that focus on measuring inputs (the number of computers delivered, number of teachers trained) or outputs (number of students who can use *Excel*). While such evaluations provide a mechanical overview of *what* occurred, they fail to measure impact—*why* and *how* an outcome occurred and the depth and life-cycle of the occurrence. Because evaluation budgets tend to be far smaller than implementation budgets, a classroom technology program may expend its entire budget on tracking inputs with no larger examination of technology's effects—another missed opportunity in understanding the benefits (or lack thereof) of educational technology and an omission that misleadingly suggests that there may be no impact to measure.

Third, there is often confusion about evaluation related terminology, in particular, confusion between terms such as "outcomes" and "impact." Outcomes are proximal changes—intermediate effects on participants at an individual or group level. Impact, in contrast, is distal. Impact deals with longer-term changes where unit of analysis is the school or district. Causes aside, the fact remains that few national or international evaluations focus on any sort of meaningful impact.

Fourth, not only are there are no internationally comparable standards by which to measure impact of computers on student learning, there are often no local standards by which to do the same. It is often therefore impossible, or meaningless, to compare results from one classroom technology program to that of another in a different geographic location or even among schools in the same location.

Finally, impact evaluations are the most useful evaluations in gauging the effectiveness or lack thereof of the relationship between instruction, technology use and student learning. But change is not a linear or direct or immediate process. Impact takes years to accrue but many technology initiatives are short lived (1-5 years). It is difficult, in many cases, impossible, to measure impact after such a short amount of time—akin to a doctor assigning a ten-day regimen of antibiotics and then assessing their impact after day three. In reality, many "impact" evaluations are conducted in programs that are not mature enough to be evaluated; many impact evaluations fail to measure impact, measuring instead intermediate effects; and as such many impact evaluations tell only part of the story or worse, state that something is or is not working when in fact it may not have had a chance to fully mature.

The evaluation system for measuring technology's impact on student learning needs reform. It needs common standards of measurement; longer timelines for implementation and evaluation; clarity in evaluation-related terminology; a mixture of quantitative and qualitative measures so we understand the "what" and "why" of a technology innovation; and an underlying awareness that measuring impact in school settings, particularly using quantitative methods is often a tricky proposition.

Put computers in classrooms: One of the reasons computers yield such disappointing results, particularly in non-industrialized countries, is that students (and teachers) can't get their hands on them. There still remains the belief that computers are a "public good" that must be housed in a public space—the computer lab. Invariably because they are divorced from classroom instruction, these "public goods" remain under-used. Invariably because these public goods are owned by no one in particular, they suffer from the "tragedy of the commons"—ill-maintained, discarded or damaged—administrative decisions that unwittingly confer on computers the stigma of complexity and unreliability.

Computers belong in classrooms. This is where students are and this is where teaching and learning occur. This statement does not argue for widespread adoption of 1:1 computing initiatives, about which research is still inclusive [50] [51]. Rather, with mobile laptop carts, computers can be used by students as they study math or science and can be shared equally by all teachers. In 2009-2010, Education Development Center (EDC) provided one laptop to 60 schools in six Indonesian provinces. Technology coaches taught teachers how to teach in learner-centered ways using this one computer. These professional development sessions did not focus on teaching the teacher how to use technology; they focused on helping the teacher set up collaborative activities in which students worked together using their one computer as part of classroom learning. Ninety-eight percent of the 300 teachers in the program utilized the one computer in learner-centered ways and 100 percent of teachers reported that students showed increased technology proficiency, academic achievement and improved behavior [52]. Not one computer was stolen or damaged. Children learned technology without IT classes. No labs were needed and little extra space required.

VII. CONCLUSION

Techno-enthusiasts are correct in their underlying premise about technology—computers belong in schools. Part of the mission of education is to prepare students for the world of work. The ability to use a computer has become basic 21st century literacy, like reading, writing and numeracy. For school leavers in Mumbai, Delhi or Kolkata to get a decently remunerated job, they must know how to use a computer. Students hoping to receive a university degree must be able to use a computer. Since private ownership of computers is low in many non-industrialized countries, schools must help students acquire these necessary educational and vocational skills.

Techno-enthusiasts are also correct in arguing that technology provides important educational benefits, debates about academic performance aside. Specifically, automation, access and equivalence have revolutionized education as they have other domains like agriculture and health. Students can take a final examination online and receive assessment results instantly. Teachers on remote Indonesian islands with no access to professional development can participate in professional learning opportunities via online courses and collaborate with other teachers across the globe. Teachers can compensate for poor, outdated or missing materials through Internet resources. Students who find that face-to-face school settings offer an education that is meaningless and irrelevant can opt for a more meaningful education and gain formal accreditation through online programs such as the UK's Notschool.net or through any number of online high school programs in the US. These are certainly paradigm-changing accomplishments.

But techno-dissenters are correct in their underlying premise—technology has more often than not been used poorly in schools, particularly in low-resource areas—at the expense of more necessary interventions (like upgrading teacher qualifications). The introduction of computers in schools has often been the result of priorities that have little to do with the needs or readiness of teachers and students. The creation of learning environments that remain at the heart of why we use technology and for which we strive cannot be attained by technology alone, though technology can aid in this endeavor. Such learning environments cannot be attained with technical solutions, though technical assistance is part of the solution. Rather they can begin to be attained by strengthening all components of the educational system—vision, teachers' skills, assessment, evaluation and access— so that computers can be integrated into an enabling, versus disenabling, environment. Once this occurs, we may truly be in a position to answer the question, *Does technology help or hinder student learning?*

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