Bethel, E.C., Bernard, R.M., Abrami, P.C., & Wade, A.C. (2007). The effects of ubiquitous computing on student learning: A systematic review. E-Learn 2007: World Conference on E-Learning in Corporate, Government, Healthcare, & Higher Education. Chesapeake, VA: AACE.

The Effects of Ubiquitous Computing on Student Learning: A Systematic Review

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Abstract: As technology use in education increases, interest in and implementations of ubiquitous computing initiatives have also increased. One-to-one laptop initiatives have sprung up throughout North America at the school, district, and state or province levels. This paper is an attempt to synthesize available studies of one-to-one initiatives at the K-12 level using both quantitative and narrative techniques. It is hoped that by so doing, best practices of these types of implementations can be identified.

Technology in Education

Welcomed or spurned, technology use in education is increasing. On the one hand, some advocate the educative potential of computers (Harasim, Hiltz, Teles & Turoff, 1995; Lou, Abrami & d'Apollonia, 2001; Scardamalia & Bereiter, 1996). This enthusiasm is evidenced by the spread of technology initiatives in K-12 classrooms. On the other hand, there are doubts (Healy, 1998; Russell, 1999) that technology can improve learning and concerns that it can in some ways hinder learning. It is argued that overuse of technology can actually be harmful: computer skills may be developed at the expense of essential literacy; or that technology overuse will foster dependant and isolated rather than independent and interdependent learners; or that faulty equipment may frustrate and de-motivate learners. Given the debate, there is a continuing need for the study of technology use in education.

One-to-one computer implementations

Until recently, studies of technology integration in K-12 schools have reported limited student access to technology: students learn in dedicated computer labs for select periods during the week, or in classrooms where computers are available but at ratios of several students per computer, or even in classrooms using "laptop carts" where a cart with enough laptops for a one to one ratio is shared by several classrooms so that students can use their own computer in their own classroom for select periods during the week. Now, interest is shifting to more widespread and ubiquitous technology use, that is, when each student is provided with a computer for use throughout the day. Underpinning this interest is the belief that increased access to technology will lead to increased technology use, which will in turn lead to improvements in a variety of educational outcomes (Russell, Bebell & Higgins, 2004). It is unsurprising that particular interest is being given to laptop initiatives where students are allowed to take their laptops home.

K-12 one-to-one computer implementations that provide students with internet access and laptop computers for use at school and home are rapidly increasing in number. Decreasing costs, increased portability, and availability of wireless networking all contribute to making broad

implementations feasible (Apple, 2005; Penuel, 2006). In two separate research syntheses, Penuel reports that not only does research lag behind such rapid expansion, but of the research studies that have been done, few analyze implementation outcomes in a rigorous manner (Penuel et el., 2001 & Penuel, 2006).

This paper is an attempt to determine to what extent, and under what circumstances one-to-one computing impacts K-12 student achievement, student and teacher technology use, and student and teacher attitudes by synthesizing in a systematic manner, the findings of K-12 one-to-one laptop studies. Where quantitative data are available they will be aggregated using accepted meta-analytic techniques. It is hoped that by aggregating findings in this way, a clearer picture of best practices for one-to-one computer implementations will emerge. Other studies that report outcomes but do not report sufficient quantitative data will be synthesized in a prose summary that will enhance quantitative findings. Reviews or other research syntheses will be included in the prose summary.

Methodology

Key terms were identified, which were then used as a basis for document searches. Document abstracts were examined to determine whether the document would be retrieved. A codebook was created in which all key terms and definitions; search strategies, decisions and results; retrieval, inclusion/exclusion criteria and decisions were recorded.

Terms and Definitions

Key terms were identified and defined as follows:

- One-to-one computing – each student has a computer to use for every class, every day for no less than one academic term (13 weeks). In some one-to-one programs students have full time access to the computers: that is they are allowed to take them home; in others, students can only use the computers at school. Though these two types of programs will exhibit unique characteristics, for the purpose of this study they will be both be classified as one-to-one programs and included in the study. This difference will be recorded as a study feature.
- Student achievement – the assessed performance of a student on a particular assignment, a group of assignments, or the composite or average score over a series of assignments.
- Technology use – how and to what extent the computers (and other related technologies) are used by teachers and by students. Whether technology use was self-reported or observed was coded as a study feature.
- Student and teacher attitudes – how students and teachers perceive technology. By definition, this measure is self-reported.

Search strategy

The following keywords and descriptors were used for the search: one-to-one, ubiquitous computing, laptop initiative, K-12, school, education, pda, handheld, mobile, portable, technology integration, personal digital assistant, computers. The following databases were searched using some combinations of the search terms: ERIC, ProQuest full text, ProQuest dissertations, ProQuest CBCA Education, Educational Technology Abstracts, Academic Search Premier. In addition, using the same search terms, the internet was searched using the Google search engine. Additional web resources were accessed through several online one-to-one clearinghouses: One-to-One Information Resource (http://www.k12one2one.org/), Ubiquitous Computing Consortium – Literature Review and Resources (http://ubiqcomputing.org/lit_review.html), One-to-One Institute (http://sparty.crt.net/121/research.cfm), BC Ministry Education – Laptop Initiative (http://www.bced.gov.bc.ca/onetoone/resources.htm), Govt of Western Australia, Dept of Education and Training, Notebooks for students 1:1 (http://www.det.wa.edu.au/education/cmis/eval/curriculum/ict/notebooks/). Finally, when there is evidence of the existence of a K-12 one-to-one implementation but no report can be located by other means, schools, school boards, school district offices, or other relevant governing bodies will be contacted directly to request access to reports of any evaluation studies.

Inclusion/Exclusion Criteria
Quantitative comparison

To be included for retrieval, studies must compare one to one computing in K-12 with a control condition (one to many, computer lab time, no technology, a pre-treatment condition). One to one initiatives must be school based and evaluate at least one full term (13 weeks) of instruction. Outcomes must include one or more of the following: student/teacher attitudes toward technology, student/teacher technology use, or student achievement data. Measures must be reported in a way that enables effect size extraction or estimation (quantitative data sufficiency criterion). Other reasons for exclusion are noted below.

Studies that satisfy inclusion criteria were retrieved for full text review, regardless of the type of study design: experimental (randomly assigned group comparison), quasi-experimental (comparison of pre-existing groups) or pre-experimental (one group pre-test and post-test). If the study failed to meet one or more of these criteria, the study was not included for quantitative analysis. The reasons for exclusion are organized according to the major criteria described above as follows:

- N121 (Not a One-to-One study): Conditions do not fit the One-to-One definition.
- DUR (Duration): The analysis does not consider studies in which the duration of one-to-one lasted for less than one term (13 weeks).
- IUA (Inappropriate unit of analysis):
- NSB (Not school based): One-to-one initiative not in K-12 school environment.
- DOA (Description or opinion article): An article that reflects personal opinion or a description of a specific implementation that does not report outcomes.
- RA (Review article): An article that includes a general review of findings or studies in the field will be excluded from the quantitative analysis but will be included in the narrative summary.

- QLR (Qualitative research): A qualitative study will be excluded from the quantitative analysis but may be included in the narrative summary if the study reports one or more outcomes identified for this review.
- MA (Meta-analysis): Meta-analyses addressing one-to-one initiatives will be excluded from the quantitative analysis but will be included in the narrative summary.
- ISD (Insufficient Statistical Data): Articles that do not fit the quantitative data sufficiency criterion will not be included for quantitative analysis, but may be included in the narrative summary.

Studies were coded according to the level of confidence about the decision made using a 5 point scale: (1) almost definitely unsuitable; (2) probably unsuitable; (3) doubtful, but possibly suitable; (4) most likely suitable; and (5) almost definitely suitable. Since study abstracts in general may not provide all necessary information about the study design and outcomes, a deliberately inclusive approach is taken at this stage of the project. Abstracts rated (3) or higher were retrieved.

Retrieved studies were read for final inclusion decisions and for effect size and study features coding. In effect size coding, statistical data from which effect sizes could be extracted were identified and coded according to outcome type (satisfaction, technology use, achievement) and type of statistics that will allow for effect size extraction. In study features coding, characteristics of the study that could explain effect size variability were identified and coded, for example, study design, sample size, and implementation features.

Qualitative Synthesis

Studies were found that report implementation outcomes but not in a manner that allowed for quantitative analysis. These studies usually will satisfy all the exclusion criteria listed above save for ISD – insufficient statistical data, or QLR – qualitative research. These studies were synthesized in two ways, vote count and prose summary. The vote count simply enumerates the number of studies finding a particular outcome compared to the total number of studies under review. The prose summary reports, in narrative fashion, interesting findings from the studies that directly address the research question. In addition, several reviews or syntheses of studies were identified. Though these did not fit the criteria for quantitative review, they were nonetheless retrieved and integrated into the narrative synthesis.

Preliminary findings

To date, the searches identified ninety-four studies for review. Not surprisingly, many these were interim reports of longitudinal studies. Studies of the same implementation were only retained if they studied a unique aspect of that implementation or reported data from a unique sample, otherwise only the most recent study was included. Of the ninety-four, there were twenty-five that presented unique data of implementations and that analyzed implementation outcomes. In addition there were six research syntheses or reviews. These twenty-five primary studies are synthesized below. The reviews are synthesized separately. At the time of writing,

searching and document retrieval was continuing. To date, few studies have been retrieved that report sufficient data for effect size calculation and hence the results of quantitative synthesis are not reported below. Instead all included studies are synthesized using the vote count and narrative methods.

Although the included studies reported on widely different implementations, from small private schools to huge statewide initiatives, the findings converged around common themes. Implementation goals included increasing technology use, increasing technology literacy, improving quality of teaching and learning, reduction in dropout rates/improving attendance, improving motivation and behavior, and improving academic achievement. Of the stated goals, increased technology use was reported in almost all (22 of 25 or 88%) of the studies. Though this result is expected—the more access to technology, the more opportunities to use it—even this finding is not as straightforward as it first appears. In two of the longitudinal studies (Stevenson, 2004; Newhouse & Rennie, 2001), though initial increases in technology use were reported, over time technology use in one-to-one classrooms declined to use patterns in classrooms with shared computers, suggesting that novelty accounted for at least some of the increase in technology use. Moreover, both these studies stress the importance of pedagogy that utilizes the unique affordances provided by the new technology (Stevenson, 2004; Newhouse & Rennie, 2001). Students quickly become frustrated when new technologies are forced into the same old pedagogy.

In a similar vein, the thirteen studies (52%) with data on student motivation report increases over previous levels or over non one-to-one comparison groups. Though it is often difficult to identify the proximate cause of student motivation accurately, these findings are certainly encouraging. At the same time, as with technology use, motivational increases may be due to the novelty effect. Closely related to both technology use and motivation, fifteen studies (60%) reported increases in positive attitudes toward technology. Again, of the six longitudinal studies that report attitudes toward technology, three report that differences between the one-to-one and non one-to-one groups declined. Given all these qualifiers, though, one-to-one initiatives have consistently resulted in increased technology use, student motivation, and positive attitudes toward technology.

Eleven studies (44%) report findings on technological literacy. Of these, eight report measured increases in technological literacy, while three report perceived increases. Though the number of studies reporting these increases is smaller, given the numbers reporting increased use of technology, it is unsurprising to find corresponding increases in technological literacy. Though improved attendance and discipline were frequently mentioned goals of one-to-one initiatives these were not often reported in the studies. Only four studies reported attendance figures. Of these, two report dramatic increases while the other two report no differences. Similarly, of the four studies reporting on student discipline, two report improvements while the other two report no difference. Interestingly, though not usually an explicit goal of one-to-one initiatives, improvements in the quality of teacher student interactions were reported in nine studies. Not only is this important for both motivation and discipline, but these interactions impact directly on pedagogy.

Justifiably or otherwise, the success of any educational innovation is more often than not evaluated in terms of student achievement gains, usually measured by standardized testing. As far as one-to-one initiatives are concerned, the results are not straightforward. Although in three studies, students or teachers report perceived achievement gains, the actual data paint a more complex picture. In fact, of all the studies only fourteen (56%) report actual achievement data.

Of these, six report improvements of some sort. Of these, the relationship between technology cannot be reliably established in two of the studies: one provides no comparison group data and another provides no pretest data. It should be noted that although this is a concern, in the meta-analysis, research design will be accounted for using study features coding. Not only does this minimize an otherwise thorny issue, it enables researchers to identify whether research design in this case actually leads to different results.

In contrast to the four that report reliable data on improved achievement, eight studies report no significant difference either between one-to-one and non one-to-one groups or between achievement before and after one-to-one implementations.

This is not to say that one-to-one technology has no effect on student achievement. The studies reporting increases in student achievement all report these increases in particular areas. In their evaluation of the Laptop Immersion Program at Harvest Park Middle School in Pleasanton, CA, Gulek and Demirtas (2005) found that when achievement results were controlled for prior performance, only differences in Language Arts and Writing remained statistically significant. Similarly, Lowther, Ross, and Morrison (2003) report substantial increases in writing and critical thinking achievement in their evaluation of a one-to-one technology integration using the iNtegrating Technology for inQiry (NTeQ) model. Trimmel and Bachmann (2004), in their comparison of 27 laptop with 22 non laptop students, report that while significant differences in student achievement could be accounted for by differences found in achievement on one sub-category of the testing measure used – spatial intelligence. Particularly interesting is that in three studies, (Mitchell Institute, 2004; Stevenson, 1999; CRF & Assoc., 2003) even though none of them reported overall gains for the treatment group as a whole, the authors report that within the treatment groups, low-performing students gained disproportionately.

Russell and Higgins (2003) raise another issue. They question whether standardized paper and pencil tests accurately measure the particular learning that might take place in a one-to-one classroom. In particular, they report research where two groups of students, a one-to-one group and a control group, take two versions of the same writing test, a computerized version and paper and pencil version. Predictably, on the computerized version, the one-to-one group had higher scores than they did on the paper and pencil test, while the control group had lower scores than they did on the paper and pencil test. In other words the unfamiliar test format tended to under-predict the performance of both groups. Moreover, they repeat the oft-heard argument that standardized tests do not measure the kinds of skills that one-to-one learning may be developing, for example spatial reasoning and problem solving. Though care must be taken with arguments of this sort, the findings of Trimmel and Bachmann (2004) and Lowther et al. (2003) seem to support this line of reasoning.

The six research syntheses reviewed echo the findings described above: they report consistent findings of increases in technology use and technology literacy, while reporting little evidence of a "technology effect" on student achievement. The syntheses report several factors contributing to the success of any one-to-one implementation: teacher beliefs, teacher training, technical support, comprehensive curriculum review that meaningfully integrates technology rather than forces into existing pedagogy, change management strategies. These findings were particularly useful for determining categories of study features for the meta-analysis. Most importantly, though, the syntheses emphasize the need for more research into one-to-one implementations to tease out exactly how, when, and under what conditions they are the most effective.

Preliminary Conclusions

Taken together, available evidence of ubiquitous technology integration is consistent – laptop initiatives have shown improvements in technology integration, use, and proficiency, in attitudes towards technology and the promise of technology for learning, and to some extent increased engagement and motivation. What seems clear, however, is that research does not support the premise that one-to-one initiatives automatically lead to increased student achievement. Of the twenty-five studies of one-to-one implementations reviewed, fourteen provide data on student achievement. Of these, six provide some evidence of achievement gains, four reliably, while eight cite data of no significant difference. Technology seems better suited to affecting improvements in some areas and with some students more than with others. Moreover as the results reported in Lowther et al. (2003) seem to suggest, the best results are obtained when one-to-one computing is one part of a well-planned technological integration strategy that includes specific guidelines and training in pedagogically sound uses of computers in the classroom.

References

Apple Computer, Inc. *Research: What it says about 1 to 1 learning*. Retrieved March 24, 2007, from http://www.ubiqcomputing.org/Apple_1-to-1_Research.pdf.

CRF & Associates. (2003). *The impact of Plato Learning, Inc. Technology in East Rock Magnet School*. New Haven, CT: East Rock Magnet School. Retrieved March 24, 2007, from http://www.eastrock.org/downloadfiles/east_rock_impact_study.pdf.

Gulek, J., & Demirtas, H. (2005). Learning with technology: The impact of laptop use on student achievement. *Journal of Technology, Learning, and Assessment*, *3*(2). Retrieved January 25, 2007, from http://webdev.shorelineschools.org/instruction/tech/pdf/jtla(1-1impact).pdf.

Harasim, L., Hiltz, S., Teles, L., & Turoff, M. (1995). *Learning networks: A field guide to teaching and online learning*. Cambridge, MA: MIT Press.

Healey, J. (1998). *Failure to connect: How computers affect our children's minds for better and worse*. New York, NY: Simon & Schuster.

Lou, Y., Abrami, P.C., & d'Apollonia, S. (2001). Small group and individual learning with technology: A meta-analysis. *Review of Educational Research*, *71*(3), 449-521.

Lowther, D., Ross, S., & Morrison, G. (2003). When each one has one: The influences on teaching strategies and student achievement of using laptops in the classroom. *Educational Technology Research and Development*, *51*(3), 23-44.

Mitchell Institute. (2004). *One-to-One Laptops in a High School Environment: Piscataquis*

Community High School Study Final Report. Portland, ME: Mitchell Institute. Retrieved March 24, 2007 from http://www.mitchellinstitute.org/Gates/pdf/One-to-One_Laptops_Report.pdf.

Newhouse, P., & Rennie, L. (2001). A longitudinal study of the use of student-owned portable computers in a secondary school. *Computers & Education*, *36*(3), 223-243.

Penuel, W. R., Kim, D. Y., Michalchik, V., Lewis, S., Means, B., Murphy, B., et al. (2001). *Using technology to enhance connections between home and school: A research synthesis*. Menlo Park, CA: SRI International.

Penuel, W. (2006). Implementation and Effects of One-to-One Computing Initiatives: A Research Synthesis. *Journal of Research on Technology in Education, 38*(3), 329.

Russell, T. (1999). *The no significant difference phenomenon*. Raleigh, NC: North Carolina State University Press.

Russell, M., Bebell, D., & Higgins, J. (2004). Laptop Learning: A comparison of teaching and learning in upper elementary classrooms equipped with shared carts of laptops and permanent 1:1 laptops. *Journal of Educational Computing Research*, *30*(4), 313-330.

Russell, M., & Higgins, J. (2003) *Assessing the effects of technology on learning: Limitations of today's standardized tests.* Chestnut Hill, MA: Technology and Assessment Collaborative, Boston College. Retrieved March 19, 2007 from http://escholarship.bc.edu/intasc/3.

Scardamalia, M. & Bereiter, C. (1996). *Computer support for knowledge-building communities*. In *CSCL: Theory and practice of an emerging paradigm*. Mahwah, NJ: Erlbaum.

Stevenson, K. (1999). *Evaluation report - year 3: Middle School Laptop Program, academic year 1998/99*. Beaufort, SC: Beaufort County School District. Retrieved March 11, 2007, from http://www.beaufort.k12.sc.us/district/evalreport3.htm.

Stevenson, K. (2004). *Liverpool Central School District: Evaluation report - year 3 High School Laptop Computer Program for school year 2002/2003*. Syracuse, NY: Liverpool Central School District. http://www.liverpool.k12.ny.us/Laptops/3rdyearevl.pdf.

Trimmel, M., & Bachmann, J. (2004). Cognitive, social, motivational and health aspects of students in laptop classrooms. *Journal of Computer Assisted Learning*, *20*(2), 151-158.

Note

The references listed above are those referred to in-text only. A complete list of studies included in the review is available upon request.