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Analysis of Laptop Computer Use in Science

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ABSTRACT *An analysis of laptop computer use in K-12 science is reported. Criteria for the analysis included the InfoTech hierarchy of use (Owen, Calnin, & Lambert, 2002), models of laptop use (Rockman Et Al, 1997), and grade level. The analysis sample was systematically drawn from ERIC and Wilson Select databases. Findings show that laptop computers are used more often in secondary than elementary and middle school science classrooms for activities, such as preparation and presentation of student work, management of data, inquiry learning, problem solving in class, and outdoor activities. Improved student achievement and writing skills, increased participation by disadvantaged and minority students, and enhanced learning among students with learning disabilities are some of the outcomes. The nature of the input device has an effect on problem solving. These and other findings are discussed and policy implications are identified.*

KEY WORDS: *Laptop computer use, science teaching, policy implications*

Introduction

This paper presents an analysis of laptop computer use in K-12 science. In this age of information technology and globalization, "more and more jobs demand advanced skills, requiring that people be able to learn, reason, think creatively, make decisions, and solve problems" (National Research Council, 1996, p. 1); therefore, the need for computer literacy is paramount. Students must be able to use computers for gathering, organizing, analyzing and displaying data. As Rowe (1993) said, "our society needs problem solvers who have access to both the information relevant to a problem and the strategies for solving it... More than any other educational innovation, the personal computer is useful for both these purposes. It can store and assimilate, in different ways, vast number of facts and rules and it can assist in the development of flexibility of thought" (p. 58). Over the past decade, personal computers have become increasingly ubiquitous in the form of palm pilots and laptops. For example, laptop computers enable students to take their computing environment with them beyond classroom walls and manipulate information with flexibility. Laptops are also known as PowerBooks (Macintosh), Notebook (IBM), and Pen-point (NCR) computers. They are like binoculars, moved in and out of their settings without leaving an impact (Carter, 1998). According to Mills (2000), the ubiquitous aspect of laptops is paving the way for a paperless education system. In a digest on laptop computers, Belanger (2000) noted that "research has shown educational benefits from the use of laptops, particularly with respect to increasing student motivation and creating more student-centered classrooms" (p. 3). However, very little is known about their role in science education, particularly how they "make new types of learning opportunities in science education possible" (Valanides, 2003, p. 42). The objective of this paper is to analyze the literature on the use of laptop computers in science education.

Analysis Framework

Frameworks (hierarchies) for analyzing computer use in education range anywhere from the utilization framework (e.g., learning about computers, learning from computes, learning with computers, and learning about thinking with computers) proposed by Luehrmann (1982) and later augmented by Kinzer, Sherwood and Bransford (1986) to the Infotech Curriculum framework proposed by Owen, Calnin, and Lambert (2002). The dynamics of these and other frameworks change with the developments in software, hardware, and curriculum applications of computers. The ubiquitous computing power of laptops is unique and is gradually transforming curriculum in general and science education in particular into an "InfoTech" curriculum (Owen, Calnin, & Lambert, 2002). The InfoTech curriculum framework is an appropriate framework for analyzing contemporary laptop computer use in science education.

Infotech Curriculum Framework

According to Owen, Calnin, and Lambert (2002), an "InfoTech curriculum is more than just an alternative to computer education approaches that have been traditionally offered in schools. There is a move away from a situation where the teacher has the major control over the knowledge acquired by students. The InfoTech curriculum is a quadratic involving teacher, students, content, and notebook [laptop computer] use. In an InfoTech curriculum, students have individual access to their own notebook computer, which is integral to the day-to-day learning activities planned by the teacher...[and] students come to regard the computer almost an extension of themselves" (p. 137). Advantages of the InfoTech curriculum include the following: Flexibility in classroom organization, enhanced acquisition of problem solving and research skills, and increased opportunity for independent learning (Owen & Lambert, 1996).

From this context Owen, Calnin, and Lambert (2002) described the following hierarchy of computer use in degree of complexity in an InfoTech curriculum:

1. *Support*: The computer is used for presenting student-generated work including word processing and multimedia presentation, and enhancing data management (e.g., storing data on spreadsheets/databases, presentation graphics).
2. *Link*: The computer is used for individual communications, such as sending and receiving email, participating in videoconferencing, etc.
3. *Resource*: The computer is used for accessing information and related resources (e.g., searching the Internet and electronic databases).
4. *Tutorial*: The computer is used for activities to enhance learning by providing individual feedback on knowledge and skills, such as drill and practice.
5. *Curriculum Adjunct*: The computer is used to facilitate and improve the teaching and learning of a specific subject such as science (e.g., graphing, journals, diaries, data analysis, using science software).
6. *Curriculum Alternative*: The computer is used as an alternative teaching and

learning approach (such as robotics, mathematica, and anatomy software) to accepted practices.

7. *Exploration and Control*: The computer is used to enhance problem-based learning, discovery/inquiry learning, decision-making, and testing solutions to problems and hypotheses (e.g., simulations, such as the Scientists in Action, and Microworlds).

As noted earlier, the InfoTech hierarchy is comprehensive and takes into consideration complex science skills and processes (Owen, Calnin, & Lambert, 2002). The hierarchy provides a systematic way of looking at laptop computer use in science classrooms. More details on the InfoTech hierarchy are presented by Owen, Calnin, and Lambert (2002).

Other variables in the analysis are grade level (secondary, middle, elementary) and models of laptop use (Rockman Et Al, 1997). The models are: Concentrated Model - one computer per student for use at school and/or home; Dispersed Model - a few laptops (5-20) per classroom and limited mostly for school use; Class Set Model - a set of laptops on carts purchased by school and available for teachers and their students; Desktop Model - laptops are purchased and permanently set in laboratories for student and teacher access at scheduled times; Mixed Model - any combination of the previous models.

Method

The analysis of literature on laptop computer use in K-12 science proceeded as follows.

Sample

The Education Research Information Center (ERIC), and WilsonSelectPlus databases were searched for sources of information on laptop computers in science. The search resulted in 82 sources presented in Table 1. These sources were screened for articles addressing laptop computer use in K-12 science education, resulting in a sample of 16 journal articles, conference presentations, and reports from North America, Australia, Asia, and Africa.

Table 1
Analysis Sample (N = 16) Grouped by Continent

Africa		**North America**
	THE Journal, 2003	Anderson-Inman, Knox-Quinn, and Horney, 1996
		Carter, 1998
Asia		Fouts and Stuen, 1997
	Rysdale, 1997	Franklin, 1991
		Hounshell, Hill, and Swofford, 2002
Australia		Kumar, and Helgeson, 1996
	Newhouse, and Rene, 2001	McMillan and Honey, 1993
	Stoularchuk, and Fisher, 2001	Parks, Huot, Hamers, and H.-Lemonnier, 2003
		Raaflaub, and Fraser, 2002
		Rockman Et Al, 1998
		Siegle, and Foster, 2000
		Tomei, Huth, and Ravenstahl, 2001

Analysis and Results

The sample was analyzed with the InfoTech hierarchy of use, models of laptop use, and grade level use. The results are summarized in Table 2. The common grade level use is the secondary level (88%) followed by middle (13%) and elementary (13%). (This includes 19% overlapping use at all grade levels.) The concentrated model appears to be the most common model of laptop implementation (56%). In the InfoTech hierarchy of use, support (81%), exploration and control (69%), and resource (56%) emerge on the top, followed by curriculum adjunct (44%), curriculum alternative (25%), link (25%) and tutorial (19%). (These include overlapping hierarchy of use.)

Table 2
Summary of K-12 Science Laptop Computer Use Analysis

Category	Percent Use (N = 16)
Grade Level Use*	
Secondary	88
Middle	13
Elementary	13
Model of Laptop Use**	
Concentrated	56
Dispersed	6
Class Set	6
Mixed	13
Infotech Hierarchy of Use**	
Support	81
Link	25
Resource	56
Tutorial	19
Curriculum Adjunct	44
Curriculum Alternative	25
Exploration and Control	69

NOTE: *Includes three overlapping Grade Level Use, 13% sample did not identify Grade Level Use; **Rockman ET AL (1997); ***Includes overlapping Hierarchy of Use Owen, J. M., Calnin, G. T., & Lambert, F. C. (2002).

Discussion

The results must be interpreted with caution. Laptop computers are used more often in secondary than elementary science classrooms. The treatment of science at the secondary level is amenable to laptop use as students engage in searching information, gathering data, analyzing data, and publishing their reports and findings. Quite contrary to what one might expect concerning the hierarchy of laptop computer use in science, they are widely used as support - for word-processing, creating multimedia presentations, and doing spreadsheets, and as exploration and control - for problem-based discovery/inquiry learning. They are also used as a resource - for researching information on the Internet, and as a curriculum adjunct - for alternative teaching and learning. Laptops are used to a lesser extent as a link - email communication, as a curriculum alternative to accepted teaching strategies, and as a tutorial – for individualized feedback. It is difficult to limit the use of computers to any one level of the hierarchy since most instructional activities in science overlap to varying degrees and complement each other. Examples of laptop uses in K-12 science follow.

Laptops are used to increase opportunities for socio-economically disadvantaged students to learn science (*THE Journal,* 2003). Through a Mobile Science Center equipped with a laptop, students in various remote parts of South Africa were able to learn science experiments in chemical reactions, data collection, analysis and interpretation including graphing. Fouts and Stuen (1997) in a study of laptop use among disadvantaged students noted that "while a number of teachers felt that student projects and the resulting products were in some ways relatively sophisticated, there was not agreement among the teachers as to the degree to which that represented increased understanding of a particular subject matter" (p. 11). They also found positive attitudes toward "potential value" of laptop application in learning among teachers, students and parents, and moderate dissatisfaction among other teachers and parents.

Laptops are also widely used for exploration and control as evident in the "Problem with Plastics" and "Seed Germination" projects (McMillian & Honey, 1993). Students collected data on the amount of plastic materials disposed per home, and interacted nationally with distant schools to pool, compare, and analyze the data. In the Seed Germination project, students raised plants, made a hypothesis, kept track of rate of growth data in a database, analyzed the data, and tested their hypothesis. They repeated this experiment under various conditions and presented their findings through computer-generated outputs. Students were allowed to take their computers home and they were able to communicate with their teacher. McMillian and Honey (1993) noted that most students followed procedures without really understanding that they were really forming and testing hypothesis based on the data they collected. The classroom teacher was concerned whether the students understood the project variables.

Kumar and Helgeson (1996) reported the effect of Pen-Point (NCR) and PowerBooks (Macintosh) laptop computers on problem solving among three groups (White, African-American, and Hispanic) of high school students. Students solved a chemistry molarity problem using a custom-developed software (HyperChemistry) on one of the laptops. The software was programmed to keep track of student problem solving protocol in the two fields, the Work Field and the Reasoning Field. Students were required to solve the problem in steps in the Work Field and to provide the reason for each step in the Reasoning Field. The findings indicate that the Pen-Point computer with pen input has a more positive effect on chemistry problem solving than the PowerBooks with key input for all ethnic groups. All three groups made more entries in the PowerBooks than in the Pen-Point computer. All three groups increasingly agreed that "I would like to use computers for problem solving," and "I felt comfortable working with computers" (p. 128) from PowerBooks to Pen-Point.

A curriculum alternative example of laptop use is evident in a controlled experiment reported by Siegle and Foster (2000). Secondary Anatomy and Physiology students viewed the inside of the human body using the Animated Dissection of Anatomy for Medicine software on laptops, developed Powerpoint presentations, reviewed course materials, and showed improvement in course grades (Siegle & Foster, 2000).

In an outdoor science activity on reforestation of pasture land, female students were encouraged to use laptop computers to actively engage in science learning and express their "intellectual" abilities through generating forest maps, managing core sampling data, and re-evaluating dispersion patterns (Carter, 1998). Reported outcomes of this study include improved self-esteem and intellectual challenges for girls to excel in science (Carter, 1998).

In a study of psychological factors and students' attitudes in science and mathematics classes using laptops, Raaflaub and Fraser (2002) noted the following: science classes had significantly higher scores than mathematics classes on actual and preferred attitudes toward the subject, and computer usage and investigation; males scored higher than females on attitudes toward the subject and towards computers; and females scored higher than males on preferred teacher support, actual and preferred cooperation, and equity. This study raises equity issues in laptop use in science and mathematics.

Newhouse and Rennie (2001) in a longitudinal study found that most students showed positive attitudes toward computers and laptop use in problem solving in science. However, their study noted an issue; teachers with high ability students spent more time preparing students for entrance examinations and less time on laptop based science.

Fouts and Stuen (1997), in a study of laptop use in elementary and secondary grades, noted that in the case of disadvantaged students using laptops, "the kid who struggled with the material is more likely to keep trying" (p. 12) when using a laptop. Hounshell, Hill, and Swofford (2002) reported a project where minority students, after attending a two-week seminar offered by a local university, used laptops in their integrated mathematics and science course. Besides creating their own websites, 90% of students said laptops helped them "make better grades." Students with learning disabilities received individualized instruction using laptop computers in science, created concept maps on the topic Agricultural Water Pollution, synthesized information, and prepared report outlines (Anderson-Inman, Knox-Quinn, & Horney, 1996). In the area of creative writing and presentation in science involving less motivated students, Franklin (1991) reported the following observation. "When he [a reluctant student] was given a laptop he retreated to a quiet part of the room and produced a comprehensive (350-word) well-written science report that generated an A from the teacher" (p. 42). Stolarchuk and Fisher (2001) found a significant negative correlation between "strict" laptop classroom environments and "enquiry skills," and a significant positive correlation between "Leadership," and "Helping/ Friendly" and "Enquiry skills."

Summary and Policy Implications

In K-12 science, laptop computers are often used on-campus in secondary classrooms for preparing and presenting student projects, data management, decision-making, inquiry activities, and problem-based learning, with improvement in student achievement and writing skill. They are used for both in-class and outdoor activities. Minority and disadvantaged students tend to benefit from laptop use, and their participation in science improves. Students with learning disabilities seem to enhance study strategies as they access and manage science information using laptops. The kind of input (key board, induction pen) seems to impact student problem solving in chemistry using laptops. Whether these are novelty effects caused by ubiquitous computing is an important question. Also, whether the laptop by itself, or in conjunction with other multimedia presentation software used in some of the studies analyzed, impacted the outcomes is uncertain (Siegle & Foster, 2000). On the other hand, the impact on science achievement if every student has access to a ubiquitous computer is another critical question that must be taken seriously by educators, researchers and policymakers. The fact that most of the literature sources analyzed are from North America demonstrates the disparity in affordability of ubiquitous technologies. How to enable science education in developing nations to reap the benefits of ubiquitous technologies is another important question with implications for education, technology and socio-economic policy. The small sample size in this study shows the need for more evaluative information on classroom use of laptop computers in K-12 science. In-depth evaluations of the nature of the product, process and especially the context of technology implementations are essential to gain an understanding what works and what does not in science classrooms, and to make informed decisions on policy and practice (Kumar & Altschuld, 2002). Ubiquitous technologies are only tools, and how they are utilized in K-12 science will determine their impact on student learning.

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