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ABSTRACT

This paper summarizes the literature on research studies in informatics and changes in learning, particularly computer-assisted instruction. Research results themselves are often inconclusive when no allowances are made for different generations of hardware and software or computer types, when the computer is treated as the only variable in the scenario, or when the epistemological roots of classroom practice are not acknowledged. Contradictory commentary springs from the fundamental dichotomy between the mechanistic and constructivist approaches. Their vastly different perspectives create disagreement over whether classroom computers actually affect cognition, and for how long. (Contains 31 references.) (BEW)

Informatics and changes in learning: The American dilemma—opposing epistemological perspectives and unanswered questions

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The subject's very much too wide,
And much too deep, and much too hollow,
And learned men on either side
Use arguments we cannot follow.

Hilaire Belloc

For every complex question, there is
a simple answer—and it's wrong.

H. L. Mencken

Introduction

At first glance, reviewing the literature on informatics and changes in learning would seem straightforward—analyze the data from research studies (perhaps discussing whether effect sizes should be used), and report the results. In fact, this has been done ably by many commentators (Collis, 1990; Roblyer, Castine and King, 1988; Kulik, Bangert and Williams, 1985; Bangert-Drowns, Kulik and Kulik, 1985; Okey, 1985; Roblyer, 1985; Stennett, 1985; Carter, 1984; Crosby, 1983; Kulik and Bangert-Drowns, 1983; Willett, Yamashita and Anderson, 1983; Kulik, Kulik and Cohen, 1980; Edwards, Norton, Taylor, Weiss and Van Dusseldorp, 1975; Jamison, Suppes and Wells, 1974; Vinsonhaler and Bass, 1972).

But the reviews have presented contradictory commentary—in part because the reviewers are relying on different criteria for success. Similarly, the reviews often do not distinguish between results achieved by one generation of software and hardware and another, and yet the different generations—and even different brands— may have different effects. Differing points of view will result in attention to different concerns and questions. For example, we *could* ask: Are the results of experiments conducted in mainframe settings the same as those conducted with personal computers? Do all Integrated Learning Systems produce similar results? And if not, why not—what differences in design cause what changes in learning? We haven't asked those questions because few researchers worry about such issues.

Other questions need to be asked, including: If it is the case that current CAI /lessonware (or Logo or some other intervention) does not produce significantly greater gains for students, why doesn't it, and what is needed instead--changes in design and/or changes in pedagogy external to the CAI/lessonware? If changes are found, can we be certain they are directly attributable to the use of technology, or to a combination of technology and other implementation variables; and, if so, what are the important variables? If changes are found, do they indicate "true" changes in cognition, or are the results ephemeral? Is CAI/lessonware (or Logo, or other interventions) the only way to promote greater understanding of concepts and algorithms, or could better pedagogy do the same? Are the current designs of software programs insensitive to the learning requirements of some groups of students, or all students? If so, what design features pose problems for which groups of students? Should students who are thought to be working below grade level be exposed to constant doses of drill, or does complementary work with problem solving effect the consolidation of skills? Are manipulatives needed to enhance the development of some or all concepts, even when whose concepts have been drilled via computer? Is *any* type of instruction conducted with technology necessary, or sufficient? Under what conditions should drill be used in educational settings? How appropriate are the measures used—both for the intervention in question, or for any type of assessment of educational progress?

Such questions acknowledge the complexity of teaching and learning, but too few studies conducted on the impact of drill or any other "treatment" address those and other issues in a complex way. The vast majority of published studies act as though introducing computers was not complex, and that the computer was the only variable—often ignoring studies which were conducted in pre-computer days, but which have relevance for the field of informatics. Similarly, many of the studies assume that there is only one pedagogical tradition—drill and practice and teacher-dominated classrooms. Few distinctions have been made between diverse sets pedagogical practices and their impact, so we may read that "computers don't make a difference," when the result really may be "computers used solely for drill that is not linked to other classroom practices don't make a difference."

A major problem with most of the current research, at least the research conducted in the American tradition, is that the epistemological roots of the research and classroom practice are not acknowledged. Research does not occur in a vacuum. It is rooted in one or another epistemological tradition—mechanistic or constructivist, for example—, and questions raised by researchers working in one tradition will not satisfy those working in the other tradition. This discussion will re-state the fundamental differences between the mechanistic (or behaviorist) perspective and the constructivist perspective, will contrast the questions about informatics' impact posed by the differing perspectives, and discuss the implications of the perspectives. But before beginning, let it be clear that this is not a continuation of the debate about quantitative vs. qualitative methodologies. Both have a place in the researcher's repertoire. The question is not which to use, but what are the assumptions of the researcher using either method. We must realize that the quantitative method can be used for answering questions based on the constructivist as well as the mechanistic perspective. But framing hypotheses, and choosing what to look at and how to measure distinguish mechanists from constructivists.

Fundamental differences between perspectives

Opposing epistemological perspectives have engaged philosophers and psychologists in debates for centuries—Locke versus Descartes, Skinnerians vs. Piagetians. In fact, the title of this conference can be interpreted differently by mechanists and constructivists. The mechanists say the software *acts on* the individual; constructivists say the individual *interacts with* software, and changes in cognition or affect *may* occur—but not necessarily—, and what is changed may depend on what is to be learned. Similarly, opposing definitions of "change" will be offered. Mechanists define learning as a "change in behavior over time." So, if a child using drill and practice software progresses from saying numbers randomly—7, 2, 10, 4, 6 as children at a certain age do—to chanting some or all of the multiplication tables, the child will have been said to change. But the constructivist will say that perhaps the child is merely parroting information which will not be used when presented with the problem "Three children have two cookies each. How many cookies altogether?" Constructivists will say change cannot be said to have taken place until that which is to be learned is integrated into generalized schemes of knowing and acting. Mechanists say externally supplied repetition and reward are key ingredients in assuring that learning occurs; constructivists say the learners' intrinsic needs and interests propel learning, and that hands-on learning, especially for young children, is essential to work out the solution of many tasks. Mechanists say standard designs of instructional materials, such as we see with many drill and practice programs, apply to all learners, while constructivists say that learning experiences must match the learners' stages of development—what works for one learner may not work for another learner sitting nearby. (Marshall, 1991)

Commentators, among them Reese and Overton (1970), say the mechanist perspective "reflects a model of man as a reactive organism ... a Newtonian perspective." Constructivist theories, in contrast, are rooted in a model of man as "spontaneously active"—an Einsteinian perspective. Kaplan (1966) says these positions are "irreconcilable, and even prevent full communication," so different criteria for determining the truth of propositions makes a reconciliation impossible. But in America, many researchers act as though (or do not know!) these differences do not exist, and ask questions as though those were the only questions to be asked. They fail to acknowledge that different perspectives focus attention on different questions. Many researchers and commentators, unaware of Kuhn's (1970) discussion about changing paradigms in science and their impact on the conduct of research, assume that using an experimental design ensures that no biases creep into the experiment—not realizing that framing the question and all subsequent assumptions made by the researcher are rooted in the perspective—mechanistic, constructivist, or whatever—of the researcher.

Questions about the impact of informatics

Research on the impact of informatics conducted from a mechanist perspective has asked:

° Does the computer enhance children's numerical and cardinal counting skills?

Children were exposed to either a computer program or flannel board instruction in numeral recognition and cardinal numbers. The mean number of correct responses for each group was compared.

° Does computer assisted instruction in spelling promote greater learning for "learning disabled" students than paper and pencil drill?

Children were exposed to a form of drill in spelling and the mean number of correct responses for each group was compared.

° Which promotes the learning of basic mathematics facts—flash cards or computer-based drill?

Children were exposed to drill in subtraction and division facts delivered by either flash cards or computer, and performance on the two treatments was compared.

Those studies, and others conducted from the mechanistic perspective, make simple comparisons on an index—the number of "correct" responses, for example, assuming the difference in treatment, and only the difference in treatment, is important.

In contrast, constructivists are likely to ask:

° How well does CMI manage arithmetic drill?

Children were exposed to mathematics drill, and then the researcher administered paper and pencil tests to check whether they could perform more problems correctly with the paper and pencil. Given discrepancies (low achieving students worked 13 levels higher with paper and pencil tests), the researcher then analyzed the software and hypothesized that the software design may have adversely affected students' performance.

° Can students using microcomputer-based labs (MBLs) improve their ability to interpret graphs?

Interviews showed that children were deficient in their ability to interpret graphs, so children first constructed graphs and predicted what data would look like on graphs. Then, they worked with MBLs, interpreting the data generated.

° What is the effect of writing with word processors and with pen and pencil?

Children spent a year with at least one class period a week devoted to writing. Although students had the same error rate in both groups, the types of errors differed—the computer-user made more mechanical errors, more sentence fragments and more "empty" words than pen writers.

So constructivists are likely to emphasize the structure of the task, the thinking skills required to perform the task, and the differences in qualitative performance between different methods of teaching. Typically, constructivists ask how thinking changes as the result of an experience.

Few research studies have been conducted to assess the persistence of effects—another legacy of the mechanistic perspective. Assuming a photocopy and an association with previously established ideas, a mechanist believes that once something is taught it remains. But constructivists believe that unless the new materials become assimilated into existing operative structures the persistence of the effect should not be taken for granted. Few studies have asked questions to test either set of beliefs.

When I began working on this paper I purposely set out to ignore the debates about Logo's impact, but the Logo question looms large in any discussion of the impact of informatics. One way to approach the issue is to try and clarify the fundamentals. Papert's (1987) comments about Logo are a part of the fabric of constructivist thought—learning cannot be forced and occurs through a series of accommodations to provocations, some of which are raised by the learner's curiosity, and some of which result from external-to-the-learner demands. So, in the world of Piagetian research children *do* learn to conserve quantity, and they (for the most part) do construct logical multiplication. But is the internally developed adaptation of conservation, which is only partly fueled by formal educational experiences, the same as learning Logo? The research, both that conducted by Papert and his colleagues and that conducted by others with whom Papert has disagreed (Pea, 1987), suggests there is a difference between learning to conserve and learning Logo. At the very least the difference is this: the ability to conserve is developed through successive encounters with natural, non-arbitrary events, so the learner constructs scenarios which expand or change as new seemingly dissimilar but structurally similar encounters occur. In contrast, Logo is a man-made, arbitrary system, and little support for learning its commands is provided by day-to-day activities, although many activities may support the awareness of concepts such as circle and square, rotation, etc. In this respect, learning Logo is like learning a language and the computer should be viewed as transparent. Working from that perspective, research on Logo's impact could be analogous to research developed to look at children's language development—i. e., examine what commands children use spontaneously, and examine the difficulties children face in using various other commands, analyzing the common properties of these commands (Brown, 1973; Lovell and Dixon, 1965; Brown and Bellugi, 1964). Pea and others have chosen to examine the classroom, focusing on the contribution of the classroom variables, and Govier's (1988) review of Logo research suggests specific instructional strategies ought to be examined more closely. Surely, many sets of questions are fruitful—the hallmark of good research.

And Becker's (1990) suggestions about the rigor of the research that should be conducted is both on target and irrelevant. Yes, research which is conducted using the experimental and control group method ought to have better designs, and no, many of the questions can only be initially approached by using methods similar to those used by language development researchers in the early days of their work. At some point there will probably be a convergence of data. For example, Entwhisle (1966) reported on a research program that collected thousands of word associations from young children, adolescents and adults—an interesting exercise, but one which, at first thought, doesn't go very far. The results were published with little commentary, and were part of the fabric of Associationist research. (Many researchers call the methodology a form of "dust bowl empiricism"—cellect whatever is out there and let the dust settle.) Later, when research paradigms changed and the language developments researchers and other constructivists began asking different questions, a second look at Entwhisle's data showed some interesting patterns. Young children tended to give functional associations ("hole" - "dig") while adults used the same category ("hole" "cave")—a finding consistent with the patterns of cognition described by Piagetian research. I suspect that when good questions are asked (and to date few good questions have been asked), we will find good theory-making or good theory-supporting data buried among the dust of a small number of studies. Perhaps a Chomskian (1957) revolution in appraisals of Logo impact are in order. A new perspective on Logo and new research strategies consonant with that perspective may answers questions more fruitfully.

Three major questions are often ignored in the design, conduct and analysis of computer classroom research: (1) what is the theoretical stance of the project to be implemented and what are the criteria by which we judge the fidelity of the implementation to that stance? (2) what is the link between the theoretical stance and what actually occurs? and (3) has implementation occurred? (Charters and Jones, 1973) Since a mechanistic perspective assumes a "photocopy" version of reality, it is assumed teachers will automatically teach their students in the same way, or at least in a manner faithful to the authors' intent. Constructivists are more likely to be skeptical about teachers' fidelity to the designers' intentions. Stallings (1975) showed us that differences in theoretical perspectives can be part of the design of classroom activities and, when implemented faithfully, can result in different outcomes. Commenting, Resnick and Leinhardt (Stallings, p. 124) seconded the need to look at what happened in classrooms. Given the differences in teachers' epistemological perspectives, researchers should not assume that implementation automatically will occur as the designers planned. We can conceive of the following set of possibilities:

		Teacher Perspective	
		Mechanistic	Constructivist
Classroom Practice	Mechanistic	✔	✖
	Constructivist	✖	✔

So a mechanistic teacher using materials based on a mechanistic perspective will probably deliver them with some degree of fidelity. But the same teacher working with materials based on a constructivist perspective may "deform" the materials, and constructivist teachers will similarly "deform" programs intended to deliver drill. In fact, we have evidence of this from informal classroom observations and from teachers' comments on software evaluation forms returned to publishers.

That fidelity or the lack of it impacts students' performance. Observations of classrooms participating in an experimental mathematics program show some teachers rarely implement problem solving mathematics lessons as the designers intended, and their classes showed a commensurate reduction in performance compared to students of similar ability in high implementation/high fidelity classrooms (Marshall & Herbert, 1984). Yet many computer studies have failed to confront the fidelity/strength of implementation issue.

Conclusion

Given the data from existing research studies, including problems with research designs, the use of measures which have questionable reliability and validity, the small sample sizes, and the fact that few studies are designed to test theories about the impact of informatics, Collis's comment that "(T)here are no easy answers or simple conclusions about the impact of computer use in education," (1989) is right on the mark. The problem is exacerbated by the fact that many teachers reading a research study have no way of knowing whether computers will make a difference in their classrooms because the question is framed in a tradition that differs from their own pedagogical practices.

A media backlash against computer use has already occurred in the United States, based in many cases on superficial analyses of poorly designed studies or on studies which represent only one side of a pedagogical tradition. It behooves computer-using professionals to address fundamental questions associated with computer use, conducting research which acknowledges the roots of the research tradition, and to provide reliable, valid finely detailed studies of the computer's impact in order to marry the best of technology with the best of pedagogy and the best of research. The current body of research has not yet begun to tell the story as it should be told.

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