The Influence of Computer and Internet Use on Teachers' Pedagogical Practices and Perceptions

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Abstract

This study explores the possibility that in schools where an informational and social support network is available and where a sufficient technological infrastructure is in place, computer use may be a powerful catalyst leading to more constructivist practices on the part of teachers. Survey research at 153 schools of the National School Network provides evidence that under these favorable circumstances, teachers' sustained use of computers and exploration of Internet resources is related to their increased use of constructivist teaching practices and may even change teachers' pedagogical beliefs that underlie such practices. The relationship between computer use and pedagogical change is particularly strong among secondary teachers in social studies, science, and noncore subjects. This article discusses three alternative theories to account for the observed correlations.

Teachers' pedagogical philosophies and practices are not static. Despite patterns of teaching that persist across decades (as documented, for example, by Cuban, 1993), the climate in which teachers practice their craft sometimes contains discourse that encourages or pressures teachers to modify their teaching styles and even their underlying beliefs about good teaching.

One widespread discourse among educational leaders and researchers encourages changes in teaching practice consistent with constructivist theories of learning (e.g., Brooks & Brooks, 1993). These discussions incorporate arguments of educational theorists such as Dewey (1916), Piaget (1952), and Vygotsky (1978) that provide a rationale for practices including

- designing activities around teacher and student interests rather than in response to an externally mandated curriculum,
- having students engage in collaborative group projects in which skills are taught and practiced in context rather than sequentially,
- focusing instruction on students' understandings of complex ideas rather than on definitions and facts,
- teaching students to self-consciously assess their own understanding,
- engaging in learning in front of students, rather than presenting oneself as fully knowledgeable.

These "constructivist-compatible" instructional activities are quite distinct from a "transmission" view of learning that emphasizes teacher-centered whole-class explanation and closely scripted student seatwork and that suggests that students acquire concepts and skills through listening, copying text, and practicing sets of similar problems (Pea, 1996).

Although teachers can use a diverse range of approaches to implement constructivist-compatible teaching, policy makers increasingly are recognizing the potential role of computers for implementing constructivist approaches. As reported by the Panel on Educational Technology of the President's Committee of Advisors on Science and Technology (PCAST) (1997), "the real promise of technology in education lies in its potential to facilitate fundamental, qualitative changes in the nature of teaching and learning" (p. 33). A move toward a student-centered constructivist paradigm offers "the most fertile ground for the application of technology to education" (PCAST, p. 35).

Researchers also have suggested that computers can help teachers accomplish constructivist approaches that might be difficult, if not impossible, to accomplish otherwise (Jonassen, Carr, & Hsui-Ping, 1998). Some arguments stress the unique ways that computers can be used to analyze data and represent complex ideas symbolically. Others stress how computers can help students produce a professional-looking presentation before an adult audience. Still others point to the rich array of easily accessible and relevant information computers provide for students to explore subjects and issues of particular interest to them.

Of course, not all uses of computers necessarily support constructivist teaching; indeed, until recently, the most common uses of computers in schools have been for supporting traditional skill- and fact-oriented instruction (Becker, 1994). Nonetheless, it is plausible that, *under the right conditions*, computers might enable teachers to implement a constructivist approach that they otherwise would not even attempt, while traditional uses of computers may merely give teachers some motivating resources to use in teaching the competencies they would have emphasized anyway.

CONSTRUCTIVIST VERSUS TRADITIONAL TEACHING PRACTICE

In this article, we conceptualize four categories of teacher beliefs and practices that have contrasting constructivist and traditional poles. These are (a) the tasks given to students, (b) the structure of the curriculum, (c) general teaching style, and (d) related perceptions.

Student tasks that are taught from an constructivist approach often resemble work in the real world; that is, they are "authentic" activities (Jones, 1994) such as producing a product that is useful to someone else. Such activities usually require students to use a wide range of skills, deal with a wide range of complex and often ambiguous issues, and make much more significant choices and decisions than traditional tasks require. Planning and decision making are the student's responsibility, not the teacher's. Sometimes, the tasks are even chosen by students to meet their own prior interests and self-assessed needs.

The *curriculum focus* in constructivist settings is often thematic and interdisciplinary. Certain issues are explored in depth, sacrificing broad coverage for the goal of making intellectual issues meaningful and substantively engaging. The curriculum focus is also more self-consciously procedural rather than factual—students may learn about how scientists think, for example, rather than what science says about a particular topic. Other procedural skills that are inherently interdisciplinary are attended to as well: "project management skills, research

skills, organization and representation skills, presentation skills, and reflection skills" (Jonassen et al., 1998, p. 29).

A *teaching style* that is associated with constructivist beliefs typically is characterized by a strong emphasis on facilitating student initiative rather than closely scripting student tasks. If understanding cannot be "taught" and must be "constructed" by the learner, students must be given more responsibility and the "space" to develop their understanding. A second element of a constructivist teaching style is having students work in collaborative teams. Having them work in teams makes sense for two reasons: (a) Exposure to other students' thinking is intellectually challenging, and (b) collaboration may be more likely to develop a social expectation supportive of learning that may be absent in many individuals (Brown, Collins, & Duguid, 1989).

The teacher's modeling of effective learning is another central aspect of a constructivist style. By presenting himself or herself as a learner rather than as the source of most information, the teacher shows students how something previously not understood comes to be successfully negotiated.

Finally, apart from student tasks, instructional content, and teaching style, we would also expect to see in constructivist settings different teacher *perceptions* of what their teaching practice is like and different opinions about the environmental features that facilitate good teaching.

The literature on school change points to the importance of having a collegial environment for enabling innovative practices to emerge. Meier (1990), for example, emphasizes that teachers need to work together to support new teaching practices, while Rogers (1983) establishes how innovators benefit from networking with others about new ideas. Constructivist projects also tend to take a greater amount of unbroken time to accomplish. Thus, we might also expect teachers to feel the need for longer class periods and to report students spending more time on their own outside of class on constructivist-oriented projects.

COMPUTERS AS FACILITATORS OF CONSTRUCTIVIST PRACTICE

As long as there have been computers marketed to schools, there have been advocates for their use in classrooms. But until very recently, computers have played a relatively limited role in schools—primarily, they have been used as a supplementary activity after more necessary work is done or in computer lab settings where students perform a uniform task, learning the mechanics of using software or gaining practice in computational or grammatical skills to the point of automaticity (Becker, 1994). Until recently, the limited range of software, impenetrable "user interfaces," logistically complex handling of computer disks, and insufficient availability of computers have made computer-dependent approaches only marginally relevant to the creation of constructivist classrooms on a large scale.

Although most teachers' classrooms still have too few computers to be used effectively, the technological infrastructure associated with computers and software has advanced substantially in the past three or four years. Computer-based tools, resources, and facilities are now present that were rarely found as recently as 1992: modestly priced high-speed personal computers; local area networks for storing and distributing software and student work; CD-ROMs and the World

Wide Web for giving students easy and rapid access to voluminous multimedia information; electronic mail for asynchronous written communication to anyone, anywhere, at any time; and a variety of components that together enable students to produce, demonstrate, and communicate their own understandings visually as well as verbally, to other people anywhere in the world.

The literature on computers and constructivist reforms describes a variety of activities that are permitted with the use of computers that are not feasible otherwise. Jonassen and colleagues (1998) describe the use of computers as "MindTools" that "require learners to think harder about the subject matter domain being studied while generating thoughts that would be impossible without the tool" (p. 30).

Honey and Moeller (1990) report that of the two groups of teachers they studied, those who were computer users and those who were not, teachers who made the greatest use of computers uniformly exhibited constructivist practices, including collaboration, project-based work, and hands-on activities with their students, and that computers facilitated their teaching in these ways.

In high-technology schools such as the Apple Classroom of Tomorrow, it was found that as teachers developed more experience with computers, they began to use them with their students primarily as productivity tools, rather than as vehicles to teach skills. "The use of computers thus serves the role of change agent within the classroom environment, affording and stimulating reflection, redesign, and change" (Wilson, Teslow, Cyr, & Hamilton, 1994, p. 9).

Electronic mail and related Internet-based collaborative tools represent another constructivist-compatible application of computers. By facilitating written communication among students across diverse school settings, e-mail may foster a richer negotiation of common understanding among different individuals and classes (Fishman & Pea, 1994; Hunter, 1993; Koschmann, 1996; Riel, 1989). This use of computers clearly represents a shift from seeing understanding as accomplished by instruction and private study to one that views learning as more of a "conversation," accomplished through efficient written communication (Koschmann , 1993; Reigeluth, 1994; Romiszowski & Ravitz, 1997).

In summary, existing research and development support our hypothesis that teachers' computer and Internet use may be related to the development of constructivist teaching practices and to a set of fundamental beliefs about learning and good teaching that might underlie such practices. Thus, although computers may be used more widely to support transmission-oriented instruction, this study asks whether teachers who have used computers to a greater extent are, in fact, more likely than others to report changes in their teaching towards a perspective that is consistent with constructivism.

THE PREREQUISITE CONDITIONS UNDER WHICH COMPUTERS MIGHT FACILITATE CHANGE

Just because computers may potentially facilitate the ability of teachers to engage in constructivist teaching doesn't mean it necessarily will happen. It is important to understand the conditions under which this pedagogy arises and becomes a normal part of day-to-day practice. The literature on school reform indicates that constructivist-oriented practices such as those suggested here re-

quire a number of conditions before they can be successfully implemented (Means & Olson, 1995).

Three types of resources may be critical in enabling teachers to institute new practices: opinion supportive of change, social and informational support that provides practical help to those attempting changes, and a sufficient supply of needed resources that can help demonstrate success to a skeptical outside world. It seems reasonable to think that all three of these resources must be present for substantial change in pedagogy to occur.

- *Opinion climate.* Like all of us, teachers are affected by the local climate of peer opinion—in their case, opinion about competing instructional priorities, alternative teaching strategies, and the compromises that are necessary in their particular circumstances. Without a local culture favorable to constructivist innovation, it does not seem likely that many teachers would make the heavy investments of time and energy that are required.
- *Information and social support resources.* Because constructivist teaching is difficult to do well, its accomplishment with or without computers may depend on being in a network of people trying to accomplish the same kinds of changes and being in a network of information for how to accomplish those changes. Both a local network and a broader network linking a school's teachers to like-minded practitioners in other places might be necessary, or at least would facilitate, teachers' efforts to persist in constructivist innovation.
- *Appropriate educational resources in sufficient quantity.* Finally, for the kinds of activities consistent with constructivist models, a diverse array of materials, equipment, and information and communications resources is also critical. These resources, though, must be present in sufficient quantity for teachers to plan activities for an entire classroom of students.

Under these favorable circumstances—where local opinion and discourse favors pedagogical practices consistent with constructivist learning theory, where an information and social support network exists to facilitate successful implementation, and where computer and communications resources exist in sufficient quantity and quality—we theorize that the use of technology facilitates changes in teaching in the direction of constructivist-oriented practice.

Research Questions

The question of the relationship between computer use and changes toward a constructivist approach to teaching can be divided into two empirical subquestions:

1. To what extent is use of computer-based technologies associated with a greater likelihood of teachers changing their practices in a constructivist direction?
2. To what extent do teachers acknowledge the role of computer technologies in facilitating their changed practices?

If experience with high levels of computer technology facilitates the emergence of constructivist practice under appropriate conditions, then teachers who have used computers longer and with greater regularity should, on average, re-

port more changes in their teaching style and other practices than teachers who had not used computers. Similarly, if experience with computers and the Internet were having that effect, teachers would likely acknowledge that that was so, or at least to acknowledge the impact of technology more than teachers who hadn't used computers with students very much.

Again, it is important to remember that we are proposing to investigate these questions under relatively favorable conditions: where we presume the social climate is favorable (or at least not hostile) to constructivist innovation, where teachers have at least some structured access to a network of like-minded teachers and educational reformers, and where there is a substantial infrastructure of computer technology that can be used as resources for constructivist teaching.

DATA SOURCE AND METHODS

This article reports on the experiences of 441 teachers employed in 151 U.S. elementary and secondary schools that are part of an entity called the National School Network (NSN). The NSN was established several years ago by a group of enthusiasts for high-speed connectivity between school classrooms and the worldwide Internet. As a "testbed" research and development project sponsored by the National Science Foundation (NSF), the NSN formed a loose confederation among more than 100 different organizations who were playing a role in fostering Internet use in K–12 schools. (More accurately, groups within those organizations were working with selected practitioners in individual schools.) For the most part, the active members in the NSN were individuals who were personally committed to instructional reform and working on a local, regional, or national scale in implementing some aspect of constructivist reform in a modest number of specific school sites. These include school districts and intermediary and state agencies investing relatively heavily in telecommunications infrastructure and staff development, science museums with active projects in individual schools, projects in universities and other organizations that were developing tools and resources for the educational use of the Internet, private firms piloting programs in schools, and pioneering individual schools with strong site leadership in educational reform and technology. (See Hunter, 1997, for a summary of the NSN's activities.)

Interest in Internet use is not necessarily identical to belief in the appropriateness of constructivist pedagogy, but the articulated rationale and the associated leadership activities in the NSN clearly had a constructivist message from the start. First, the NSN proposal for NSF funding relied heavily on an image of students being producers of content and "resources" for other people using the Internet, such as other community groups who may lack even modest expertise in technology. Second, in an effort to diffuse "authentic" uses of the Internet, the NSN continually publicized to its membership efforts it identified where students used the Internet to address problems and needs in their local community. Finally, in its third year, one of the NSN's most visible activities was the organization and support of live Internet events in which students engaged adults in questions about their real-world activities.

Between 1994 and 1997, the NSN and its constituent organizational members recruited more than 300 schools to participate in communications and col-

laborate in Internet-related projects for teachers and classes of students. During the spring of 1997, 248 of the NSN schools were surveyed—those schools which met the qualification of having LAN-based high-speed Internet connectivity for at least 10 computers for at least the previous 12 months. Actually, for this sample, the average number of simultaneous connections was nearly 100, and most schools had high-speed connections for at least two years. The 1997 survey had a number of goals, including studying changes in telecommunications use that had occurred at these schools over the previous two years.[1] However, one small part of the data collection concerned the nature of pedagogy among a sample of teachers at each school. It is from those data that we investigate the current question about the relationship between teachers' use of computer technologies and changes in their teaching practice.

Two groups of teachers were sampled for this part of the study: three of the 10 "most active Internet-using teachers" at their school, as identified by their school networking coordinator, and two other teachers sampled from among the remaining teachers rostered by the networking coordinator (sampled alphabetically). Because probability sampling methods were used within schools, each teacher was assigned a weight that was the inverse to their probability of selection, so that the analysis could be conducted as if a representative sample of teachers from these schools was selected.[2] Thus, whereas "raw" data analysis would have privileged the more selective group of "most active Internet users" who were oversampled, the analysis in this article uses weighted data to create a sample that is representative of all of the teachers at the 153 participating NSN schools.

Of the 726 teachers sampled in the 153 NSN schools that participated in the study by returning a completed teacher sampling roster, 441 teachers (61%) completed and returned their own survey questionnaires. Response rates were nearly identical for the two teacher subsamples (the most active Internet users and other teachers). The 441 responding teachers included roughly 140 who taught primarily at the elementary grades (K–5), 130 middle-grade (6–8) teachers, and 170 high school (grades 9–12) teachers.

Respondents were split into eight groups defined by the subject they taught, along with some grade-level distinctions. These eight groups are:

- 54 secondary (middle or high school) science or science and math teachers,
- 36 secondary mathematics teachers,
- 52 secondary English or English and social studies teachers,
- 30 secondary social studies teachers,
- 99 elementary teachers of self-contained classes,
- 57 teachers of classes in computer subjects (primarily or exclusively),
- 62 other elementary- or middle-grade teachers, and
- 50 high school teachers of other subjects

The individuals selected as most active Internet users completed a detailed 54-question survey booklet that asked largely about their use of the Internet. The

[1] *Additional research on the NSN can be found in Becker (1995) and Becker and Ravitz (1997).*
[2] *The high-end Internet users were sampled with probabilities dependent upon the reported frequency of Internet use by themselves and by their students. The remaining teachers were sampled with probabilities related to their overall use of computers.*

remaining teachers completed an abbreviated instrument containing the first 15 questions from the longer booklet. Those 15 questions given to all participating teachers asked about (a) the teachers' teaching responsibilities, (b) their uses of various types of computer software, (c) their perceptions of the Internet and its relevance for their own teaching, (d) the extent to which they believed that each of 19 aspects of their teaching practice and related perceptions (Table 1) had changed during the last several years, (e) whether they believed that "computers have been a primary or contributing factor to that change," and (f) whether they had "already found the Internet to have had an impact on your teaching in that way."

This article examines the changes that these teachers perceived in their teaching practice and environment (d) and about the relation of these changes to their use of computer software (b and e) and the Internet (c and f), taking into account their teaching responsibilities (a).

Dimensions of Change in Teaching Practice

The analysis focuses on the several dimensions of teaching practice discussed at the start of this paper (student tasks, curriculum, and teaching style) and the rates of self-reported "changes...during the last several years" reported for particular measures of those dimensions of practice that are shown in Table 1. These 19 items represent changes in teaching practices and perceptions that would be consistent with a constructivist perspective.

Eight items dealt with changes in student tasks, one dealt with curriculum, and five items dealt with changes in teaching style. In addition, the analysis includes five measures of changed perceptions related to their teaching practice that might be expected as one adopts a more constructivist outlook—one item about longer blocks of time being needed for good teaching practice, two items reporting changes in their own involvement in collaborative professional activity, and two items regarding changes in the nature of students interactions and work outside of class that they have observed.

Outcome Variables

To measure teachers' use of computer technology, we used information about four aspects of technology use that were included in the survey questionnaire given to all teachers:

- the teacher's own use of computers,
- the teacher's assignment of computer activities to students,
- the teacher's use of the Internet with their classes for student learning, and
- the teacher's preference for software that is productivity-oriented rather than for knowledge transmission or skill acquisition.

For "teacher's own use" and "teacher's assignment of computer activities," we had data on how many years teachers had used computers that way *at all*, and how many years teachers had used computers that way on a *frequent* basis ("daily" in the case of personal use; "weekly" in the case of teacher-directed student use).[3]

[3] *Both any use and frequent use were indicated by a six-point scale whose choices were "none," "a bit," "1–2 years," "3–5 years," "6–10 years," and "11+ years."*

Table 1. Self-Reported Changes in Teaching Practice and Related Perceptions Studied

	Compared to several years ago...
Student Tasks	
Students Review and Revise Work	I more often have students review and revise their own work
Active/Out-of-Seat Work	I more often have students get out of their seats and work actively in the classroom
Address Real-World Problems	I more often have students address problems linked to real-world contexts
Students Work Independently	I more often have students explore a topic on their own, without procedural direction
Student Interests Govern Task	I more often have students select their own topic based on their own interest
Long Projects	I more often have students work on long projects
Students Do Work Used By Others	I more often have students do "real work" that is put to use by someone or some group
Student Choice of Task	I more often let students decide themselves what they want to work on or what materials or resources to use
Curriculum	
Interdisciplinary Content	I more often teach units and lessons that are interdisciplinary, building in topics from other courses or subjects
Teaching Style	
Reflective About Goals	I have become more reflective about basic teaching goals and priorities of different outcomes
Skill in Cooperative Groups	I have gained more skill in organizing cooperative work groups
Skill in Multiple Parallel Activities	I have gained more skill in orchestrating multiple parallel activities in the classroom
Being a Coach or Advisor	I find myself more often in the role of coach or advisor and less often in the role of instructor
Being Willing to Be Taught By Students	I more often discuss a subject which is fairly new to me and allow myself to be "taught" by students
Related Perceptions	
More Contact with Other Teachers	I have been more involved in conferences and workshops and activities that bring me into contact with more teachers
Students Offer and Give Peers Advice	My students more frequently offer advice and seek advice from one another

Table 1, cont.

	Compared to several years ago...
Related Perceptions	
Need Longer Blocks of Time	The need for longer blocks of time/longer periods is much more apparent than before
Students Take Initiative Out of Class	More of my students are taking initiative outside of class time—for example, doing extra research or polishing their work
More Time in Joint Planning	I spend more time working with other teachers on curriculum and instructional planning

The extent of a teacher's use of the Internet in the classroom was based on a single four-point scale: (1) "students do not use the Internet for my class(es)"; (2) "students have used the Internet for my classes, but on their own"; (3) "my students use the Internet, but under the direction of another person (media specialist, lab aide, or other teacher)"; and (4), "I have directed and supervised my students' use of the Internet."

The teacher's preference for productivity-oriented software was a very rough measure based on the respondents' checking the four types of software that were most valuable in their teaching—that they'd find the hardest to do without. The measure used is the number of software types, up to four, that the teacher selected from our "productivity" category. Software was counted as "productivity-oriented" if it was "tool" or general reference software rather than subject-specific software or knowledge- and skill-oriented programs. Subject-specific software is more likely (though not necessarily) to reflect a knowledge-transmission pedagogy, with "an implicit commitment to the existence of a 'correct' representation (of reality) and a view of the tutor as an agent for effecting the learner's acquisition of this representation" (Koschmann, 1996, p. 8).[4]

RESULTS

For all but two of the self-reported measures of changes in practice, a majority of respondents reported changes in the indicated (constructivist) direction during the past several years of teaching. Table 2 shows the weighted percentages of teachers reporting each change, by the grade level of students that they mainly taught. Teachers of elementary grade students reported, on average, more changes than teachers of middle or high school students (12.9 vs. 11.9 and 11.2, respectively). Among the eight subject-matter/level groups, secondary English

[4] *In general, these "tool" or "general reference" types of software can be used by students in almost any subject area and therefore the focus may be on more generalizable cognitive or productivity skills. In particular, we counted in the productivity category word processing, database, and spreadsheet programs, general reference materials on CD-ROM, drawing or painting software, desktop publishing and presentation tools, Internet software, authoring software, image-editing and multimedia development software, programming languages, Web development tools, and CAD/CAM programs. Examples of software not counted as productivity-oriented included gradebook software, typing practice software, video-cassettes and laserdiscs, as well as subject-specific software for English, math, social studies, science or foreign languages.*

Table 2. Percentage of Teachers Reporting Recent Changes in Their Teaching Practice By Grade Level

	Grade Level			
Changes in the Direction of (More)...	Elementary	Middle	High	Total
Student Tasks				
Students Review and Revise Work	77	68	70	71
Active/Out-of-Seat Work	83	73	64	71
Address Real-World Problems	61	68	75	70
Students Work Independently	49	48	64	56
Student Interest Governs Task	72	57	43	54
Long Projects	53	53	50	52
Students Do Work Used By Others	50	53	52	52
Student Choice of Task	64	39	36	43
Curriculum				
Interdisciplinary Content	88	80	54	70
Teaching Style				
Reflective About Goals	85	87	82	84
Skill in Cooperative Groups	82	79	62	72
Skill in Multiple Parallel Activities	86	68	61	69
Being a Coach or Advisor	77	56	68	66
Being Willing to Be Taught By Students	59	61	56	58
Related Perceptions				
More Contact with Other Teachers	62	76	69	70
Students Offer and Give Peers Advice	69	70	69	69
Need Longer Blocks of Time	68	57	64	63
Students Take Initiative Out of Class	64	50	52	54
More Time in Joint Planning	58	50	43	49

teachers and "computer" teachers (i.e., those who primarily or exclusively teach classes in the use of computers) reported the greatest mean number of changes (13.6 and 13.4, respectively). The groups reporting the least frequent changes in practice were high school teachers of in noncore subjects (i.e., outside of the academic core of English, math, science, and social studies) (9.3 changes per teacher) and secondary mathematics teachers (9.9).

We cannot say whether the self-reports of changed practice and perception are accurate, either individually or collectively. Overreporting of behaviors perceived to be socially desirable is a common finding in survey research. However, even in such situations, comparisons among groups of respondents or between different response items is much less problematic (Wentland & Smith, 1993). Thus, much can be learned from differences in the relative frequencies of different self-reported changes or in the differences between groups of teachers reporting about the same pedagogical practices. When we find substantial differences between groups (expressed either as differences in means or percentages or correlations between pairs of characteristics), then we presume those differ-

ences represent true differences in the prevalence of changed practice between the compared groups of teachers.

Correlation Between Technology Involvement and Pedagogical Change Index

The major empirical question addressed is whether teachers who have invested effort and implemented regular use of various computer technologies over the past several years are more likely than other teachers to have made the kinds of instructional and professional changes associated with constructivist reform ideas.

The basic bivariate analyses are shown in Table 3 (by grade level) and in Table 4 (by subject matter and level). Overall (see rightmost column in Table 3), two of the four measures of technology involvement—longevity of computer use with students and teachers' involvement in Internet-based teaching activities—were clearly associated with greater breadth of change in teaching practice and related perceptions. The other two measures—the longevity of the teacher's own computer use and their choice of productivity software over other software—had only a limited relationship to the breadth of changes reported.

Table 3. Correlation Between Teachers' Computer Use and Self-Reported Changes in Practice and Perceptions By Grade Level

	Correlation with Number of Constructivist Changes Reported			
	Elementary	Middle	High	Total
Teacher's Own Use of Computers (longevity of *any* and *frequent* use)	.07	−.01	.04	.02
Teacher's Practice of Assigning Computer Work to Students (longevity)	.15	.28	.48	.38
Longevity of Any Computer Use	.00	.40	.33	.30
Longevity of at Least Weekly Computer Use	.18	.13	.54	.38
Teacher's Choice of "Constructivist" Types of Software as Most Valuable	−.05	−.09	.18	.05
Teacher's Involvement in Internet-Based Instructional Activities for Students	.26	.23	.50	.37
N	122	122	158	402

Note. Correlations are based on weighted N; actual (real) N shown in table are minimum N present for all bivariate associations.

In general, relationships were stronger among high school teachers and weaker among elementary teachers. For example, how long teachers had assigned computer work to students was correlated with constructivist oriented changes in pedagogy and perception for middle and high school teachers, $r = .40$ and $r = .33$, respectively, but not for elementary teachers. And, how long teachers had assigned computer work to students "every week" was associated with the reported changes for high school teachers, $r = .54$—but only marginally for elementary or middle school teachers. Similarly, the correlation between a teacher's use of the Internet with students and the change measures was twice the size for high school teachers, $r = .50$, as for teachers at lower grade levels.

Table 4. Correlation Between Teachers' Computer Use and Self-Reported Changes in Practice and Perceptions By Subject Taught

	Correlation with Number of Constructivist Changes Reported							
Level:	Elementary	Elementary and Middle	Middle and High School				High School	All
Subject Within Level:	Self-Contained	Other Subjects	English	Social Studies	Math	Science	Other (noncore)	Computer Teacher
Teacher's Own Use of Computers (longevity of *any* and *frequent* use)	−.04	.05	.05	.00	.18	.03	−.13	.21
Teacher's Practice of Assigning Computer Work to Students (longevity)	.06	.35	.26	.77	.20	.46	.47	−.06
Longevity of Any Computer Use	−.09	.54	.15	.72	.17	.32	.27	.01
Longevity of at Least Weekly Computer Use	.06	.10	.30	.75	.22	.43	.58	−.12
Teacher's Choice of "Constructivist" Types of Software as Most Valuable	−.07	−.35	.22	.52	.12	.16	.12	.37
Teacher's Involvement in Internet–Based Instructional Activities for Students	.19	.06	.11	.17	.13	.60	.68	.20
N	86	59	50	28	35	49	44	50

Note. Correlations are based on weighted N; actual (real) N shown in table are minimum N present for all bivariate associations.

Secondary English, social studies, and science teachers (particularly social studies teachers) and high school teachers outside of the academic core subjects were the ones for whom a technology-based teaching approach is most closely associated with pedagogical change. For example, for secondary science teachers, how long they have regularly (weekly) assigned students work involving computers was correlated .43 with how many changes in teaching practice and perception they reported. For social studies teachers, this relationship was even stronger—the correlation was .75. For science teachers and the noncore high school teachers, the correlation between their use of the Internet and breadth of self-reported change was also very large, $r = .60$ for the former, and $r = .68$ for the latter.

These large correlations translate into substantial mean differences in the number of changes (out of the 19 studied) that different groups of teachers reported. Using the social studies teachers as an example, those who indicated that they had never had students use computers on a weekly basis averaged only five changes in pedagogy and perception, those who reported doing so for up to two years averaged 10 reported changes, and those who reported doing so for three or more years averaged 15 reported changes. Because the number of social studies teachers participating in the survey was rather small, $n = 30$, one should not read too much into those absolute means. However, the frequent presence of strong positive correlations for different groups of high school teachers and more than one independent measure of technology use suggests that many of these strong relationships are real and not artifacts of sampling error.

In contrast to these results for English, social studies, science, and noncore secondary teachers, none of the correlations for math teachers exceeded .25, suggesting a more modest relationship between technology use and instructional reform for this group of secondary teachers who were also, as noted previously, among the least likely to have substantially changed their practices among the teachers studied.

For only two groups of teachers was the hypothesized relationship confirmed between preference for productivity software and pedagogical/perceptual changes—for secondary social studies teachers, $r = .52$, and secondary computer teachers, $r = .37$. A possible explanation for this result is that categorizing software according to its gross "type" does not provide sufficient information about the way its use was orchestrated to determine whether its use followed constructivist pedagogical principles.

Specific Pedagogical Changes Most Related to Technology Use

The preceding set of correlations generally support the primary hypothesis of this article. In other words, those teachers who have had students use computer software in a substantial way for several years or who have been among the pioneer teachers employing Internet-based activities for classes of students are the same teachers who are most apt to report that their teaching practice has changed substantially over the past three years in ways that educational theorists would regard as indicating a constructivist-oriented model of teaching.

Now, we disaggregate the general index of pedagogical change to see which particular aspects of teaching practice are most closely associated with use of technology in teaching. For this analysis, we contrast teachers whose students

have used computers on a weekly basis for a minimum of three years versus teachers who have not used computers that frequently at all (leaving out the middle group of relatively novice regular users). In addition, we look at the responses of teachers who report that they themselves directed students' use of the Internet and contrast their responses with those who report no Internet use for their classes at all. Again, we leave out the middle group of teachers who report that students used the Internet for their class, but either under someone else's direction or at the students' own initiative.

Table 5 shows the differences between these contrasting pairs of teacher groups in terms of the percent reporting recent changes in each aspect of their teaching. The table lists the 19 aspects of teaching that were assessed, beginning with the ones showing the biggest difference between technology users and nonusers. The entries in Table 5 indicate the percentage of teachers defined by the top of the column who report having changed in the aspect of teaching summarized on the left. Thus, 71% of teachers who have used computers weekly with students for at least three years say they are more willing to be taught by students than they were several years ago. In contrast (next column), only 29% of teachers who have not yet used computers with students on a weekly basis report having changed in that respect, a difference of 42 percentage points (.42 in the column labeled "C").[5]

For 16 of the 19 aspects of teaching in Table 5, there were substantial differences between technology-using teachers and nonusers in how likely they reported having changed. Only with respect to using more "active out-of-seat" teaching approaches, being more reflective about teaching priorities, and feeling the need for longer blocks of time were there no appreciable differences between technology users and nonusers.

At the upper-end, two elements of teaching had extremely large differences (40 percentage points) between technology users and nonusers—being more willing to be taught by students and feeling more skilled in managing multiple simultaneous ("parallel") activities during teaching. We do not know whether teachers who fail to master those elements give up on using technology or simply never begin, but it seems clear that long-term success with technology involves teachers sharing the position of expert with students and teaching in ways that permit different students to be doing different things at the same time.

Most of the other pedagogical changes were also reported by substantially more technology users than nonusers. Changes reported by roughly 30 percentage points more technology users than non users included (a) increasing their use of long projects, (b) giving students more choice in the tasks they worked on or the materials they might use, (c) teaching lessons with more interdisciplinary content, and (d) observing that students now took more initiative in their school work outside of class (a change in perception rather than one of practice). Nine other changes also

[5] *The fact that in this case 71% and 29% "add" to 100% is irrelevant—they are percentages from different samples of teachers. Recall from Table 1 that the aspects of change presented in Table 5 are abbreviated versions of the prompt to respondents. For example, "being willing to be taught by students" was presented as "Compared to several years ago, I more often discuss a subject which is fairly new to me and allow myself to be 'taught' by students."*

Table 5. Percentage of Technology-Using Teachers and Nonusers Reporting Specific Changes in Pedagogy and Perceptions

	Have Students Use Computers Every Week			Student Use of the Internet for Their Classes		
	For 3+ Years (A)	Have Never Done That (B)	(C)	Teacher Directs Student Use (D)	Internet Not Used (E)	(F)
	Clear Users	Clear Nonusers	Difference in % (B – A)	Clear Users	ClearNonusers	Difference in % (E – D)
Percentage of Teachers Reporting Changes in the Direction of...						
Being Willing to Be Taught By Students	71	29	+42	78	28	+50
Skill in Multiple Parallel Activities	83	42	+41	88	49	+39
Long Projects	59	32	+27	69	30	+39
Students Take Initiative Out of Class	68	35	+33	62	35	+27
Student Choice of Task	53	25	+28	55	23	+32
Interdisciplinary Content	78	47	+31	80	53	+27
Students Offer and Give Peers Advice	79	53	+26	75	49	+26
Students Work Independently	61	40	+21	63	34	+29
Being a Coach or Advisor	72	46	+26	74	50	+24
Address Real-World Problems	75	55	+20	81	54	+27
Students Review and Revise Work	80	56	+24	79	54	+25
More Contact with Other Teacher	77	48	+29	76	60	+16
Student Interest Governs Task	62	40	+22	62	42	+20
More Time in Joint Planning	57	37	+20	60	41	+19
Skill in Cooperative Groups	76	58	+18	79	59	+20
Students Do Work Used By Others	64	38	+26	50	49	+01
Active/Out-of-Seat Work	79	67	+12	70	65	+05
Need Longer Blocks of Time	67	63	+04	66	60	+06
Reflective About Goals	86	86	+00	82	92	–10

Note. Omitted from this table are teachers showing intermediate levels of use. For "computer use," omitted were teachers who had used computers weekly but for 2 years or less. For "Internet users," omitted were teachers whose students use of the Internet is directed by other teachers or whose students use the Internet on their own initiative.

showed about a 20–25 percentage point advantage for technology users.

The differences in Table 5 for computer users versus nonusers and Internet users versus nonusers are nearly identical. The absolute differences between users and nonusers of each technology were very close. Moreover, even the ordering of differences is very similar for the computer-use comparisons and the Internet use comparisons.

The sole major difference between the "computer use" results and the "Internet use" results was that long-time computer-using teachers were more apt than non-computer-users to report increased use of assignments where students did "real work" that was put to use by other people. But this was not the case when comparing Internet-using teachers and nonusers. That finding was somewhat surprising given the emphasis the NSN has placed on developing "authentic" uses of technology (e.g., using the Internet to support community organizations). However, it is consistent with other information obtained in these same surveys, which showed that network coordinators at most participating NSN schools regarded the Internet primarily as a resource for expanding the information environment for students rather than as a means of publishing student work for an audience or broadening their real-world contact with other adults and age peers (Becker, unpublished data). The truth is that the Internet may simply be too new a technology for it to be appropriated in ways that more mature computer-based applications can be (e.g., desktop publishing or authoring of digital multimedia products).

Strongest Change—
Technology Use Relationships by Grade Level and Subject

How do these specific aspects of changed practice and perception play out among teachers at different grade levels and of different subjects? Not surprisingly, given the previous results about the general index of pedagogical change, long-time computer users and Internet users at the high school level differ profoundly from their non-technology-using peers on most of the aspects of change in the top half of Table 5. On the other hand, the pattern for middle and elementary teachers is more selective.

If we consider only the 11 aspects of change with the greatest relationship overall to technology use, at the high school level the longevity of assigning frequent computer work is at least moderately correlated (i.e., above $r = .20$) for 9 of the 11 aspects of pedagogical change. The teachers' involvement in student Internet use passes that criterion for 10 of 11 elements among high school teachers. (See Table 6.)

Among middle school teachers, the teachers' longevity of computer use is associated above .20 with only three changes—increasing skill in managing multiple parallel activities, having students work independently without specific procedural direction, and observing that students take more initiative outside of class. Involvement in Internet use among middle school teachers is associated with only one change—being more willing to be taught by students.

At the elementary level, Internet involvement is most associated with increased use of long-term projects, increased use of assignments linked to real-world contexts, and observing more advice exchanged among students. Com-

Table 6. Correlation Between Teachers' Computer Use and Self-Reported Changes in Specific Practices and Perceptions By Grade Level

Relationship with...	Longevity of Frequent Computer Use with Students			Involvement in Students' Internet Use			Preference for Productivity Software
Self-Reported Changes in...	Elementary School	Middle School	High School	Elementary School	Middle School	High School	High School
Being Willing to Be Taught By Students	.11	.30	.40	.13	.55	.44	.27
Skill in Multiple Parallel Activities	–.03	.16	.51	–.04	.19	.57	.27
Long Projects	.02	.08	.38	.35	–.02	.51	.30
Students Take Initiative Out of Class	.11	.24	.35	.19	.04	.36	.16
Student Choice of Task	–.08	–.09	.46	.16	.16	.39	.32
Interdisciplinary Content	–.07	.04	.38	.12	.10	.36	.17
Students Offer and Give Peers Advice	.11	.14	.25	.42	.13	.16	.00
Students Work Independently	.08	.21	.19	.23	.18	.26	–.02
Being a Coach or Advisor	.07	.03	.30	.07	.05	.34	–.02
Address Real-World Problems	.14	–.04	.27	.33	.07	.23	.07
Students Review and Revise Work	.39	.17	.17	.20	.17	.22	.03

puter use at the elementary level is associated with only one change—more frequently having students revise their work.

When we disaggregate the middle and high school teachers by the primary subject-matter that they teach, we find that the leading pedagogical changes we have identified for technology's possible impact on high school teachers are especially tightly associated for three groups of secondary teachers—science teachers, social studies teachers, and teachers of non-academic-core subjects. Averaging across three measures of technology use, for both science teachers and social studies teachers the correlation is strongest for increasing use of projects, more student choice of tasks and materials, improved skill in handling multiple parallel activities, and witnessing greater student initiative outside of class time (particularly the latter two changes). For the non-academic-core high school teachers, use of technology is strongly associated with all six of the changes shown in Table 7.

To give the reader an idea of how these correlation coefficients translate into concrete differences, here are a few specific comparisons from the data contributing to Table 7. For secondary social studies teachers, there is a .67 correlation between how long they had frequently used computers with students and whether they reported becoming more skilled over the past several years at managing multiple parallel activities. What does this mean? In this sample, all 12 of the social studies teachers who had frequently used computers with students for at least three years said they had become more skilled in managing parallel activities, but only one of the 7 social studies teachers who had not used computers on a weekly basis with students at all reported feeling more skilled in this way.

For secondary science teachers, the correlation between directing student Internet use and increasing the role that "long projects" play in their teaching was .55. That correlation derives from these two statistics: 94% of the secondary science teachers who directed student Internet use said they had increased project work in their instructional repertoire, but only 43% of the remaining science teachers reported an increase in their use of projects.

Finally, we have the "other" high school teachers—mainly business and industrial arts teachers, foreign language teachers, and art and music teachers. Table 7 shows almost uniformly substantially positive correlations between constructivist-oriented changes in pedagogy and these noncore high school teachers' use of computers. For example, among those who had never used computers with students on a weekly basis, only 10% reported being more willing to be taught by students; among those who had used computers frequently with students for 1–2 years, 71% said they had changed in this way; and for the teachers using computers for three years or more, 89% said they had become more able to accept students as their own "teacher."

Table 7 does not include data on English teachers, because generally speaking their pattern of correlations was more muted than for the three groups just discussed. However, interestingly, there were two very strong correlations for English teachers between the type of software they preferred and changes they reported in their own teaching. In particular, English teachers' preference for productivity-oriented software was correlated .47 with whether they reported

Table 7. Correlation Between Teachers' Computer Use and Self-Reported Changes in Specific Practices and Perceptions for Three Groups of Secondary Teachers

	Science	Social Studies	High School Noncore
Relationship with Longevity of Frequent Computer Use with Students			
Self-Reported Changes in...			
Being Willing to Be Taught By Students	.33	.18	.69
Skill in Multiple Parallel Activities	.30	.67	.74
Long Projects	.35	.42	.47
Students Take Initiative Out of Class	.35	.70	.45
Student Choice of Task	.20	.67	.59
Interdisciplinary Content	.44	.34	.44
Relationship with Involvement in Students' Internet Use			
Self-Reported Changes in...			
Being Willing to Be Taught By Students	.20	.40	.76
Skill in Multiple Parallel Activities	.34	.37	.74
Long Projects	.55	.25	.63
Students Take Initiative Out of Class	.42	−.18	.57
Student Choice of Task	.52	−.10	.67
Interdisciplinary Content	.19	−.33	.52
Relationship with Preference for Productivity Software			
Self-Reported Changes in...			
Being Willing to Be Taught By Students	.15	.08	.44
Skill in Multiple Parallel Activities	.41	.29	.40
Long Projects	−.09	.37	.44
Students Take Initiative Out of Class	.27	.56	.01
Student Choice of Task	.18	.51	.36
Interdisciplinary Content	−.10	.39	.27

having increasing their use of long-term student projects and .43 with being more willing to be taught by students.

Alternative Explanations for These Relationships

The statistics presented in Tables 3 through 7 and discussed in this article display a fairly broad and consistent picture of the covariation between teachers' involvement in computer-based approaches to teaching and whether they report having changed their teaching styles, the types of student work they give, and related perceptions about their teaching or students. These relationships are stronger and more consistent for high school teachers and particularly strong for secondary teachers in science, social studies, and areas outside of the academic core fields. The patterns are similar whether computer use is measured in terms of longevity of any use, longevity of frequent use for instruction, teacher direction of student Internet work, or the type of software preferred (although the measured associations were smaller for the latter variable). But on the whole,

and particularly for high school teachers, there is a clear and remarkably consistent pattern: Those teachers who use computer technology regularly with students, over many years, and with student productivity goals (rather than knowledge-absorption or skills-mastery goals) in mind, and who exploit new technological resources such as the Internet, are the same teachers who report having made important changes in their teaching practice and who report changes in the students they work with.

There are several ways of understanding this pattern, and these provide alternative and competing explanations for these results.

- *A theory of technology-induced belief change.* It may be that teachers who regularly use computers with their students over a number of years learn over time that they are more effective teachers when they allow students to work more independently, when they allow themselves to learn from students, and when they act more in the role of an adviser and resource than as a direct source of instruction. The theory is that computers encourage and even demand such practices which in turn change the pedagogical beliefs of teachers who use them.
- *A theory of facilitating conditions.* Alternatively, teachers who use computers regularly with students or have students exploit Internet resources may already have had personal philosophies that support independent student work, long-term projects, multiple simultaneous activities, and interdisciplinary thematic curricula, but until computers and the Internet, they hadn't had the means of implementing this philosophy in their teaching. For example, Honey and Moeller (1990) seem to suggest that this is the case with respect to students undertaking small-group work and projects in the classroom. In this view, computers and the Internet are catalysts that have enabled constructivist-oriented teachers to implement practices more in line with their teaching philosophy than those they had been using before.

  A variant of this theory is that exogenous forces such as local staff-development leadership helps produce changes in certain teachers' objectives, goals, and teaching philosophies, and that under these circumstances, the introduction of computers and similar technologies provides these teachers with an opportunity to test out their new understandings and pedagogical points of view.
- *A theory of spurious correlation.* Finally, it is still possible that neither of those theories is correct. It may be, instead, that those teachers who tend to act on their awareness of constructivist ideas in teaching that have come to the fore during the past half-decade are also the ones who are most apt to experiment with the use of new teaching resources, such as computers, multimedia, and the Internet. The fact that the teachers who report changes in pedagogy and perceptions are often the same ones who have pioneered and experimented with new technologies could really just be a manifestation of the idea that teachers who are innovative with respect to pedagogy are also more innovative with respect to technology as compared to those who might approach their job in a routine way.

The question remains, then: How can one empirically determine which of these competing viewpoints more accurately provides the reason we see such a clear

relationship between teachers' use of technology and self-reported changes in pedagogy and related perceptions, at least for these high-end Internet-using schools?

The NSN survey data allows us to investigate this question by learning what technology-using teachers themselves said about the influence of computers or the Internet on their teaching. Although self-reports of causal impact are a weak form of verification, one cannot automatically dismiss them. Moreover, if there are substantial differences in the attribution of the influence of technology between clear users of that technology and those who are more novice users, this also suggests that the impact is real, at least in the perceptions of those involved.

Teachers' Reports About the Effects of Technology on Changes They Have Made

In the survey, each teacher who indicated a particular change in pedagogy or perception was asked whether "computers have been a primary or contributing factor to that change" and whether "you have already found the Internet to have had an impact on your teaching in that way." Table 8 summarizes the respondents' answers to these two questions.

Table 8 lists each of the specific changes asked about, in the same order as in Table 5, but Table 8 refers only to teachers who had observed that change in their own practice over the previous several years. For each change, we report the percentage of teachers saying that computers or the Internet had contributed to the change they had made. Column A reports the percentage indicated by long-term regular computer users (i.e., those who have used computers with students for three or more years on at least a weekly basis or more). As a point of comparison, column B reports the percentage indicated by those who have used computers in some way, either on their own or with students for a short time or irregularly. Those individuals might be expected to be less likely to report that computers have contributed to pedagogical changes they reported; differences between the "B" teachers and the "A" teachers are shown in column C. Columns D and E give comparable percentages regarding the perceived impact of the Internet on reported changes for teachers who direct their students' Internet use (column D) and teachers whose students do use the Internet for their class but either on the students' own initiative or under another teacher's direction (column E). Nonusers of computers or the Internet are omitted from this table, as it would be implausible that many of them would attribute importance to the respective technology in the changes in their own practice they had observed.

The main interest in Table 8 is in columns A and D, the primary users of the respective technologies. Among the long-term instructional computer users (i.e., those who reported each pedagogical change), generally between 40% and 60% indicate that computers played a contributory or primary role in the change they reported. The most universal attribution for the impact of computers was on increasing the number of assignments for students to review and revise their own work (76%). Also widely reported were effects on student initiative outside of class (67%) and on the frequency of assigning long projects (65%). On average, long-term frequent instructional computer-using teachers ascribed an influence to computers in 48% of the changes they made or observed.

Internet-using teachers—that is, those who directed their own students' use of the Internet—attributed an influence on pedagogical change only slightly less often (43%) than the long-term computer users did for computers in general. The most frequent claimed effect of the Internet was on having students work more independently, exploring a topic on their own without procedural direction (80%). This was followed by a perception that computers increased how frequently the teacher orchestrated long projects for their class (70%) and how often they had students "address problems linked to real-world contexts" (62%).

It is also interesting to note that the student-directed Internet-using teachers found the Internet to have a much greater impact on their practice than did teachers who more passively incorporated Internet activities into their class (the column E teachers). Group E was much less likely to ascribe an influence on their changed practices to their students' use of the Internet. (The differences noted in column F often were 20 percentage points or more.) In contrast, even computer-using teachers who had used computers infrequently with their students or over a short period of time reported computers having influenced the pedagogical changes they had made.[6]

DISCUSSION

Although survey research techniques deal in numeric counts, percentages, and statistical coefficients, we are still at an early stage in understanding the dimensions of how various experiences with computer technology help to change how teachers go about their work. There are many advocates for constructivist-oriented reforms who pay relatively little attention to computers, and who design and implement reform programs with relatively little involvement of computers. (For example, several of the New American Schools whole-school restructuring models give only a perfunctory recognition to technology's role—see Stringfield, Ross, & Smith, 1996.) However, a number of authors have suggested that using computers successfully inevitably results in adopting a reform or constructivist view of teaching and specific teaching practices generally associated with the terms *reform* and *constructivism*. Studies of technology-rich Apple Classroom of Tomorrow schools and classrooms (Sandholtz, Ringstaff, & Dwyer, 1997), for example, argue that the process through which teachers learn the details and implictly the principles of using computers results in changed beliefs about how to improve students' understanding, competency, and performance. However, we still lack evidence about how widespread and effective computers are for helping teachers become more effective implementers of constructivist approaches to teaching.

The current study enters this fray with correlational data collected in school contexts in which other arguably necessary conditions for fostering instructional reform are already present—for example, an environment plentiful with discourse about reform, a social support and information network that is encouraging and knowledgable about how to implement changes in instruction, and a relatively technologically rich environment. We have shown that among teachers in

[6] *With one exception: Long-time computer-using teachers were much more likely than limited computer users to say that computers contributed to their increased use of student editing and revision of work.*

these schools, those teachers who report having changed their instructional practice in constructivist-oriented directions are the same teachers who have most thoroughly employed computers in their teaching and who have taken advantage of new opportunities incorporating the Internet into their instruction.

In particular, high school social studies, science, and non-academic-core teachers (most often in business and other occupation-related fields) appear to be the teachers whose pedagogy has been most affected by substantial use of computer technology. Our interpretation is that these fields and levels of study may be the ones where current school practice is most in need of change. In these classes, students are mature, on the verge of young adulthood; the subject-matter has important links to real-world concerns and activities; and, in those real world domains, successful performance requires competencies in information acquisition, critical analysis, and communication of argument through a polished product. All of these are characteristics that integral use of computers and digital communications systems can conceivably provide. However, to use technology in ways that address the goals of social studies, science, and occupation-related education, it may be necessary for teachers to move away from the whole-class-centered, textbook-centered, fixed assignment, closely monitored orientation of traditional skill-based and knowledge-transmission pedagogy. When teachers find themselves able to make those changes, computer technology appears to facilitate a successful transition.

The data suggest that use of computers and the Internet is more consistently related to certain types of changes in practice and teacher perception than others. In particular, frequent computer and Internet use seem to be related to (a) teachers being more willing to discuss a subject about which they lack expertise and allowing themselves to be taught by students, (b) orchestrating multiple simultaneous activities occurring during class time, (c) assigning long and complex projects for students to undertake, and (d) giving students greater choice in their tasks and the materials and resources they can use to complete them. All of these changes can be seen as a "letting go," a willingness to cede more authority to students instead of directing all of their learning from the front of the class. In addition, it may be instructive that a fifth clear change associated with computer and Internet use is an increasing recognition of the initiative that students take outside of class to do high-quality work.

With these findings, and with the interpretive argument we have made in the past several paragraphs, it seems that the relationship between technology use and pedagogical change is truly causal and not the mere conjunction of innovative teachers who happen to both use technology and develop a more constructivist pedagogy. However, this article still leaves unanswered the question of whether the causal impact is limited to teachers who were already inclined to teach in a constructivist manner and simply needed appropriate resources to do so, or whether the experience using computers or the Internet in a substantial way with students itself leads otherwise "nonconstructivist" teachers to rethink their pedagogical priorities and philosophies of teaching. The answer to that question has important consequences for the extent to which constructivist teaching practice can be successfully diffused throughout a heterogeneous teaching population. ■

Contributors

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Table 8. Among Technology-Using Teachers Reporting Changes in Specific Practice, Percentage Who Say Computers or the Internet Contributed to Their Change: Clear Users and More Novice Users

	Computer Use with Students			Internet Use with Students		
	(A)	(B)	(C)	(D)	(E)	(F)
	Clear Users	Novice Users[a]	Difference in % (B – A)	Clear Users	Novice Users[b]	Difference in % (E – D)
Among Teachers Reporting the Change Below, Percentage Saying Computers or the Internet Contributed to Change	Percentage Saying Computers Contributed			Percentage Saying Internet Contributed		
Being Willing to Be Taught By Students	51	35	+16	54	25	+29
Skill in Multiple Parallel Activities	49	39	+10	33	12	+21
Long Projects	65	59	+6	70	22	+48
Students Take Initiative Out of Class	67	61	+6	50	53	–3
Student Choice of Task	44	42	+2	48	43	+5
Interdisciplinary Content	54	38	+16	41	30	+11
Students Offer and Give Peers Advice	54	57	–3	35	20	15
Students Work Independently	49	40	+9	80	43	+37
Being a Coach or Advisor	50	45	+5	52	17	+35
Address Real-World Problems	39	23	+16	62	26	+36
Students Review and Revise Work	76	27	+49	6	8	–2

Note. The raw N for each row depends on the number of teachers reporting that change. The range is shown. [a] *Omitted from this column are teachers who reported almost no use of computers, either on their own or with students. Almost none of those persons who reported changes in their practice said that computers contributed to their change.* [b] *Omitted from this column are teachers who said their students did not use the Internet for their class, either through any adult direction or on their own. Few of those persons who reported changes in their practice said that the Internet contributed to their change.*

Table 8, cont.

	Computer Use with Students			Internet Use with Students		
	(A) Clear Users	(B) Novice Users[a]	(C) Difference in % (B – A)	(D) Clear Users	(E) Novice Users[b]	(F) Difference in % (E – D)
Among Teachers Reporting the Change Below, Percentage Saying Computers or the Internet Contributed to Change	Percentage Saying Computers Contributed			Percentage Saying Internet Contributed		
More Contact with Other Teachers	50	40	+10	37	20	+17
Student Interest Governs Task	48	32	+16	54	41	+11
More Time in Joint Planning	27	43	−16	33	16	+17
Skill in Cooperative Groups	34	27	+7	24	6	+18
Students Do Work Used By Others	41	35	+6	40	30	+10
Active/Out-of-Seat Work	46	28	+18	35	13	+22
Need Longer Blocks of Time	44	38	+6	47	18	+29
Reflective About Goals	27	34	−7	25	8	+17
Average	48%	39%		43%	24%	
(range of *N*)	(124–185)	(73–151)		(102–182)	(64–102)	

Note. The raw N for each row depends on the number of teachers reporting that change. The range is shown. [a] *Omitted from this column are teachers who reported almost no use of computers, either on their own or with students. Almost none of those persons who reported changes in their practice said that computers contributed to their change.* [b] *Omitted from this column are teachers who said their students did not use the Internet for their class, either through any adult direction or on their own. Few of those persons who reported changes in their practice said that the Internet contributed to their change.*