The Impact of Computer Use on the Individualization of Students' Learning Experiences in Public Middle School Science Classrooms

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ABSTRACT

THE IMPACT OF COMPUTER USE ON THE INDIVIDUALIZATION OF STUDENTS' LEARNING EXPERIENCES IN PUBLIC MIDDLE SCHOOL SCIENCE CLASSROOMS

Fiona Mae Hollands

Given the recent emphasis and significant expenditures on technology as a tool in educational reform, policymakers, educators, and taxpayers are seeking accountability in terms of evaluation of its impact. With a view to investigating how the presence of computers in the classroom has affected the process of teaching and learning, this study aims to determine whether and how computer use by public middle school students in the science classroom might facilitate the individualization of students' instructional experiences.

Questionnaires from 50 middle school science teachers located in 20 Manhattan public schools were collected to provide background information on each teacher's teaching philosophy, teaching practices, attitude toward technology, technology skills, and technology use in the science classroom. Questionnaires from 673 students of these teachers provided information regarding the students' computer use and skills and addressed issues of classroom environment deemed to be indicators of individualization of instruction. A classroom observation instrument was used to quantitatively track how 191 of these students interacted and worked with peers, the teacher, and resources in the classroom.

The relationships between degree of computer use and the indicators of individualization of instruction were investigated using multilevel statistics, accounting for the clustering effect caused by students being grouped together in classrooms, to provide a more reliable analysis than traditional single level, fixed effects models. Random intercept analyses allowed an investigation into the mediating effects of teacher and classroom variables on the various outcomes.

An increase in computer use was found to be associated with changes in certain aspects of the learning environment: fewer but more protracted verbal interactions in the classroom; more one-on-one interactions among students and between individual students and the teacher; more time spent working independently; more time spent working on assignments that varied according to the student's interests; fewer shifts in activity during a given time period; greater flexibility for students to work at their own pace; use of a wider range of resources; and greater student initiative in selecting resources to use.

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F. M. H.

Chapter I

INTRODUCTION AND NEED FOR THE STUDY

Fiscal Responsibility

Technology applications in education have been and will likely remain among policymakers' reform priorities, whether for the sake of improved productivity, greater relevance to today's work environments, or to accommodate more constructivist modes of learning. Market Data Retrieval (2002) reports that projected technology spending by K-12 public schools for the 2001-2002 academic year amounted to $5.6 billion or $118.26 per student. The Federal appropriation for technology through the No Child Left Behind Act of 2001 was $785 million for fiscal year 2002, and E-rate funding awarded across the states added another $2.25 billion. Estimates of expenditures required to attain an optimal level of effectiveness and equity range from $6 billion to $23 billion annually (Glennan & Melmed, 1996; McKinsey & Company, 1995).

To continue investment in technology-related interventions without making some attempt to sort effective approaches from ineffective ones would be fiscally irresponsible. McNabb, Hawkes, and Rouk (1999), reporting on the Secretary's Conference on Educational Technology: Evaluating the Effectiveness of Technology, state, "If resources are to be expended on technology, it is becoming a political, economic, and public policy necessity to demonstrate its vital effectiveness" (p. 1). To date, public opinion has generally supported the technology-related reforms because it has seemed self-evident that if computers could enhance productivity in nearly every major industry, schools should similarly be positively affected. However, as greater sums are spent, demands for some visible return will also grow.

In 1997, the Educational Technology Panel of the President's Committee of Advisors on Science and Technology (PCAST) published a "Report to the President on the Use of Technology to Strengthen K-12 Education in the United States" (hereafter referred to as "the PCAST Report"). The Panel states that probably their most significant recommendation is for the federal government to substantially increase its support for research to discover effective interventions in elementary and secondary education, with educational technology specifically highlighted. One of the research priorities outlined involves "empirical studies designed to determine which approaches to the use of technology are in fact most effective" (p. 91). The Panel recommends that technology should not be viewed or assessed as a stand-alone intervention. It is the educational approaches and techniques that make use of technology that need to be identified, assessed, and replicated where appropriate.

While the need for evaluating the impact of technology is great, there is clearly pressure to demonstrate positive outcomes resulting from its use in the classroom. With the government having already spent large sums of taxpayer money and made the issue so visible to the public, it is questionable whether studies sponsored by governments can be truly objective in nature. Therefore, government-sponsored studies should be supplemented by studies that are conducted by private or academic institutions with no significant stake in the findings.

Timeliness

While a great deal of research exists to support the effectiveness of computers in teaching, the research must be as up-to-date as the current hardware, software, and manner of use to be meaningful to policymakers and practitioners in today's schools. Honey, Culp, and Carrigg (1999) note that early studies of technology in schools attempted to demonstrate the impact of specific tools on student learning. The tools were usually text-based, locally networked, or stand-alone computer-assisted instruction applications. They argue that the specificity of the studies provides little information about the generalizable role that technologies can play in teaching and learning. Furthermore, these studies do not help establish indicators for optimal technology designs.

Given how recently schools have experienced the infusion of multimedia computers, Internet, and Worldwide Web access, relatively little published research is available to document the impact on students and teachers. Indeed, many educators argue that it is too early to be measuring outcomes of such interventions on student achievement.

Need to Develop Valid Indicators to Measure Growth of Desired Skills

As the PCAST Report (1997) underscores, the research on traditional applications of educational technology often fails to address whether the variables being measured are correlated with the forms of learning we wish to facilitate. McNabb et al. (1999) note that while educators have long known that technology can help students learn basic skills, the tools used to measure these changes do not evaluate the development of the ability to think creatively or critically. They stress the need to develop tools to measure the "new basics" (p. 4), including computer literacy, collaborative teamwork skills, and lifelong learning abilities. Honey et al. (1999) similarly note that the studies conducted in the 1970s and 1980s do not help us understand how technologies can engender the kinds of "sustained and substantial inquiry and analysis that we all want our children to achieve" (p. 3). Furthermore, there are tasks that students can accomplish with technology that were not previously possible, such as communicating and researching via the Internet, for which no broadly accepted metrics exist.

If, for example, policymakers and practitioners do indeed seek to facilitate the development of critical thinking skills, problem-solving capacity, research capabilities, or the ability to examine an academic issue from multiple perspectives, there is no evidence that improvements in standardized test scores are an appropriate indicator. Valid indicators of these skills are yet to be developed and used on a large scale. Heinecke, Blasi, Milman, and Washington (1999) further suggest that technologically-based performance assessments should be developed to measure the impact of technology on student learning.

Establishing the Role of Technology in Current Modes of School Reform

Honey et al. (1999) argue that a major shortfall in early studies of the effectiveness of technology to enhance student learning is that these studies treated technology as a discrete and isolated input. The treatments had little long-term impact on student learning and were not scaleable beyond the initially targeted group. Given the current trend to view technology as just one element in complex reform efforts that span administration, curriculum, assessment, time use, spatial arrangements, and so forth, Honey et al. claim that the research questions have changed. It is now important to understand how technology is integrated into educational environments, how the new resources are employed and adapted by the users, how to get the most value in terms of student learning given the technology's capabilities, and how technological change can interact with and support changes in other aspects of the educational process.

In order to answer these more complicated questions, Honey et al. (1999) believe that it is necessary to look at technology use in a social context. This involves treating technology as just one of many inputs in the more encompassing process of school change. Furthermore, it is necessary to understand how use of the technology is mediated by factors including classroom organization, pedagogical methods, and the school's socio-cultural setting.

Implicit within this call for a change in research direction is the recognition that the benefits of technology can only be realized on a large scale if factors affecting success are identified. Technology interventions can subsequently be designed accompanied by relevant adjustments to optimize the conditions within the treatment site, whether the school, the classroom, or the home.

Explaining Connections Between Technology Use and Outcomes

Studies that document technology use or availability and link it to change in educational outcomes such as test scores rarely attempt to explain the connection between one variable and the other (Norris, Smolka, & Soloway, 1999). Mann (1999) uses a pharmaceutical analogy to identify the research needed with respect to applications such as the Internet and computer learning games: "We need clinical trials that (1) identify and measure the active ingredients of instructional technology and (2) that document the gains associated with amounts of their use" (p. 5). Mann also highlights the need to establish "dosage effects" (p. 4), that is, to report outcomes in the context of actual exposure time and use of the technology. Indeed, it is remarkable that even in classrooms participating in technology initiatives such as Challenge 2000: Multimedia Project, student use of computers and other technologies ranges from only around 30 minutes to 80 minutes per week (Penuel, Golan, Means, & Korbak, 2000). It is possible that, up to a certain point, computer or other technology use will have no impact whatsoever and that beyond a certain point it might have negative effects or no marginal effects.

Only by identifying changes in process will it be possible to develop explanations of the mechanisms by which technology might affect educational outcomes. Heinecke et al. (1999) emphasize the need to recognize the complexity of educational technology and hence to "define technology as an innovative process linking teaching and learning outcomes rather than a product which is dropped into the black box of teaching and learning outcomes defined as improvements on standardized test scores" (p. 7). As Honey et al. (1999) state, the researcher's goal should be to understand how innovation occurs in schools, not simply document the outcomes correlated with the treatment. This crucial middle step in deciphering the black box of educational technology is what this study attempts to address. By identifying which practical processes are changing, it should become possible to hypothesize how the use of computers in classrooms might affect the learning process, whether positively or negatively.

Once these processes are better understood, more accurate predictions could be made about which educational outcomes should be affected. Valid measures of these outcomes could subsequently be developed for use in future studies trying to measure the effectiveness of computer technology in improving student achievement, knowledge, or skills.

Need for Generalizable Studies

Much of the research that already exists, particularly that on constructivist uses of technology, focuses on a small group of users in special situations where supplementary resources are available. For example, extra money has been granted for an initiative or technology experts are available for direction and support. Successful approaches to incorporating the new technologies are only just being identified and have not as yet been implemented on a grand scale. While these situations may indeed show the beneficial effects of computer use on student learning, they cannot be generalized to the school population as a whole. This study aims to provide more generalizable information by investigating 50 different public school classrooms spread across 20 different schools. While some of these schools may indeed benefit from a greater number of technology initiatives than others, they all fall within the range of possibilities that are open to any public school.

Relevance to and Implications for New York City Public Schools

This study focuses on New York City public schools at the sixth through eighth grade levels given the efforts by the Board of Education (now New York City Department of Education) in the last few years to introduce technology to the classroom, particularly at the middle school level. The Board of Education made both independent efforts to improve K-12 education by enhancing the availability and use of technology and also participated in many joint efforts involving corporate and academic partners, such as the Technology Innovation Challenge Grant Projects. Given the amount of money and time being spent on these initiatives, it is important to assess their impact on the classroom. Findings from the study may be used to inform policymakers, educators, and officials at the New York City Department of Education about changes in classrooms that are associated with technology use, allowing them to assess the worth of this investment.

The next chapter reviews what has already been observed in past research about the impact of computers in the K-12 classroom and explores the kinds of studies appropriate for this investigation. By identifying gaps in the existing research and evaluating the strengths and weaknesses of past research designs, potential areas for study are described before presenting the specific focus of this study.

Chapter II

REVIEW OF THE LITERATURE ON THE IMPACT OF COMPUTER USE IN K-12 EDUCATION

Since computers were first introduced into K-12 classrooms in the 1960s, in the form of computer-assisted instruction, attempts have been made to document effectiveness. How effectiveness has been defined has depended on the motivation behind the innovation. Studies have generally been focused on outcomes defined as a tangible measure of student achievement.

Cuban (1986) suggests that the primary motivation behind the introduction of computers into the classroom has been to increase productivity, that is, "students acquiring more information with the same or even less teacher effort" (p. 3). This drive for productivity stemmed from policymakers and not from teachers. Effectiveness in this context of technical rationality has often been defined in terms of improvement in indicators such as test scores, graduation rates, and college attendance. A second motivation behind school reform through use of electronic technologies has been the desire to bring schools into technological step with the workplace and more broadly to maintain economic competitiveness.

Additionally, the move toward school use of electronic technologies, particularly personal computers, has been supported by a group of educators that Cuban (1993) terms "neoprogressives." Based on the educational theories of Dewey, Bruner, Montessori, and Vygotsky, neoprogressives aim to create schools in which teachers help students construct their own understanding rather than simply absorb huge amounts of knowledge disconnected from real-life tasks. Indeed, the PCAST Report (1997) cites constructivist applications of computers as potentially one of the most promising uses of computers in schools.

Meta-analytical studies by Hartley (1978), Burns and Bozeman (1981), Bangert-Drowns, Kulik, and Kulik (1985) and Kulik, Kulik, and Bangert-Drowns (1990) capture the main findings elicited by research on traditional, tutorial-based computer-assisted instruction (CAI) applications in elementary and secondary education. These studies indicate that students using computer-based systems outperformed other students taught the same material without computers by 25-41% of a standard deviation. Traditional CAI applications are generally shown to have the strongest effects on learners who are low on the socioeconomic scale, who are low achievers, or who have special needs. Students using such computer systems often learn more quickly, enjoy classes more, and exhibit more positive attitudes toward computers, although not always to the underlying subject matter.

However positive these results might appear, such studies might be questioned on a number of bases. Many of the underlying studies have inadequate designs, others do not use enough controls to be truly robust, and yet others demonstrate only short-lived achievement gains. The objectivity of the data is further at issue considering that evaluators are not always independent and that there is possibly a bias toward the publication of positive results. In any event, this research, often being based on text-only applications on minicomputer systems, does not generally report on the kind of computer activities employed in schools today.

Beyond measures of effectiveness, policymakers' fiscal concerns have also led to studies of the cost-effectiveness of computer use in schools. In one relevant study, Levin, Glass, and Meister (1984) compared the cost-effectiveness of four interventions commonly used in an attempt to improve math and reading skills: reduction in class size, increased amounts of time dedicated to instruction in these skills, peer tutoring, and CAI. Peer tutoring was found to be far more cost-effective than CAI. CAI was a little more cost-effective than reducing class size, and increased instruction time was by far the least cost-effective. Similar studies using up-to-date computers and applications and involving the teaching of more complex skills and concepts might well render different conclusions. Such studies are still to be conducted.

A more recent and relevant study of computer effectiveness was conducted by Wenglinsky (1998) investigating the connection between computer use and the performance of fourth and eighth graders on the math section of the 1996 National Assessment of Educational Progress (NAEP). Wenglinsky found that eighth graders whose teachers used computers for simulations and applications performed better on the NAEP than those whose teachers did not. However, eighth graders whose teachers used computers primarily for drill and practice performed worse. In the fourth grade, students whose teachers used computers mostly for math or learning games performed better than students whose teachers did not. In both grades teacher professional development helped improve student scores. Students who spent more time on computers in school did not perform significantly better. Schools in which teachers received professional development in computer use and employed computers for teaching higher order skills also displayed higher staff morale and lower absenteeism rates. All effects noted were more pronounced at the eighth grade level than at the fourth grade level. As with many prior studies, however, Wenglinsky's analysis correlates inputs with outcomes but does not consider the many potential confounding factors, nor does it seek to explain the means by which technology use engendered the improved outcomes.

Far less research is available on the kind of constructivist applications of computers that allow students to direct their own learning, to explore complex concepts, and to develop their own understanding of sophisticated phenomena, that is, to develop higher order thinking skills. The PCAST Report (1997) observes that the existing research does not provide enough evidence on the positive effects of constructivist computer activities to allow public policymakers to act on it with assurance. Those studies that have been conducted are often executed with the help of expert content developers and in situations where considerable financial support for the project has been available. Whether similar results can be achieved in more typical school situations where teachers may be less motivated or trained, less well supported, and where funds are minimal remains to be determined.

One of the better known constructivist computer applications for schools is "The Adventures of Jasper Woodbury" developed by the Cognition and Technology Group at Vanderbilt University (CTGV). A series of videodisk-based problem-solving exercises allows students to develop mathematical skills in open-ended activities. In a study comparing users of the application with students taught in a traditional classroom set-up, it was found that while the experimental group developed basic mathematical skills more or less at the same rate as the control group, they outperformed the controls on more complex word problems and higher level planning tasks (CTGV, 1992).

However, as CTGV points out (CTGV, 1992, in Duffy & Jonassen, 1992), the benefits of working with the applications are not automatic but depend on effective teaching. If the elements of this effective teaching could be identified, then they could probably be adapted for successful use with a wide range of applications.

Black and McClintock (1996) report on a different set of constructivist applications termed Study Support Environments (SSEs) developed for teaching aspects of history, science, and literature at a private school in New York City. Evaluations were conducted for two of the SSEs to determine whether students who had used the programs could make observations and interpretations in a completely new area of study more effectively than students not exposed to the programs.

One application, Archaeotype, allows students to study ancient Greek and Roman history through observations of simulated archaeological digs. The evaluation study involved sixth grade students who had used the application and a comparable group of students who had not. Both groups were provided with the same information related to four psychology experiments and given a few hours to prepare reports on the findings. They were instructed to look for patterns, devise explanations, and argue for those explanations. The reports of students who had used Archaeotype indicated greater skill in explanation and argumentation than the comparison students. The fact that these skills were demonstrated in an area of study previously unfamiliar to the students indicated that they were able to transfer these abilities from one domain of study to another.

Another application, Galileo, is designed to allow students to study astronomy and science in general through observations of telescopic plates and a computer simulation of the sky. By using the program, students are able to construct and test interpretations of astronomical phenomena. The program's effectiveness in teaching observation and interpretation skills was tested by comparing the performance of a group of eleventh and twelfth grade students who had used the program with a group that had not. Both groups were given three hours to prepare a report interpreting and linking three related cognitive psychology studies and their underlying principles. Students who had used the Galileo program produced reports that demonstrated superior skills in pattern recognition, data representation, interpretation, and argumentation.

These model studies provide convincing evidence that students using constructivist applications learn not only specific content, but also outperform control groups in acquiring generalizable interpretation and argumentation skills and completing complex tasks. However, the small numbers of students involved and the exceptional amount of resources and expert help available render these idealized situations that may not be easily replicable in the typical public school. Furthermore, Black and McClintock's (1996) study was conducted in an elite private school where it is quite possible that the students had more potential for developing interpretation and argumentation skills than the average public school student. It should also be noted that in both studies the developers of the constructivist applications were also the evaluators, raising questions of objectivity. The studies do not, however, address how exactly the use of the applications led to improved skills, for example, which aspects of the software design were important and which contextual issues of use were relevant in allowing students to excel.

Aside from looking at prepackaged software applications, even fewer studies exist evaluating the use of open-ended resources such as the Internet and Worldwide

Web. In 1996, an independent research organization, the Center for Applied Special Technology, conducted a study regarding the impact of Internet access on the performance of elementary students in completing a research project (Follansbee, Hughes, Pisha, & Stahl, 1997). The study involved 627 students from 28 different classrooms selected from seven urban school districts across the United States. In each city, four classrooms were selected: an experimental and a control fourth grade class from one school and an experimental and a control sixth grade class from another school. Experimental classes were provided with on-line access to Scholastic Network and the Internet on at least one computer, and the teachers were provided with basic on-line training. A curriculum framework for a six- to eight-week civil rights unit was provided to all classes in the study. Students in all classes were asked to complete a project, and these were used to compare student learning between the experimental and control groups. Information on changing behavior and attitudes was also collected through pre- and post-study questionnaires for teachers and students.

Students with on-line access produced better projects in general than those who had no on-line access but who were otherwise taught the same material and had use of computers and other technology resources. The experimental group excelled on several performance criteria, including effectiveness in integrating different points of view and presentation of a fuller picture. These students also improved their ability to gather, organize, and present information. Experimental students reported more frequent use of computers to help with basic skills, to gather information, to organize and present information, and to do multimedia projects. Interestingly, no connection was found between the amount of time classes spent on-line and the quality of their projects. While the number of teacher questionnaires returned was too low to report statistically significant results, it appeared that teachers in the experimental classrooms learned more about the content than comparison teachers from on-line resources, as well as from their own students. They also had more positive interactions with parents during parent-teacher conferences, increased parent visits to the classroom, and greater communication with the home.

While this study is encouraging with respect to the effectiveness of on-line access in improving student performance, a number of issues compromise the value of the findings. Principals who selected classrooms to be included in the study may well have selected those led by teachers already well acquainted with on-line technologies to be in the experimental group. Consequently, the results might not reflect the impact of the intervention in a typical classroom. Furthermore, beyond meeting a minimum requirement for connectivity, it appears that classrooms may have varied on availability of hardware and the number of Internet connections. Other issues arose due to the practical problems associated with research in typical classrooms and schools. While 627 students were included in the study and all completed the pre-study questionnaire, only 293 of the 501 post-study questionnaires could be matched with pre-study respondents. No explanation is provided as to why such a large proportion of the student sample appears to have changed in the six- to eight-week period.

More generally, given the extent to which teachers involved in this study were specifically prepared to help students in Internet use, the study may not reflect the potential gains available to students working with teachers under normal school circumstances. It is also difficult to assess how much of the students' and teachers' enthusiasm was due to the novelty of the resource. This makes it difficult to predict whether effects would be sustained once on-line access became a standard tool in the classroom.

The studies described so far have all focused on the impact of technology use as measured by some form of student achievement. While they generally indicate that technological interventions have a positive effect, they do not attempt to explain how this effect is achieved.

Schofield (1995) undertook detailed observational studies of how computers, students, and teachers interact in a variety of school settings. Rather than trying to assess the impact of computers on achievement measures, she reports on the social effects of technology use. Her findings are based on a two-year study (1985-1986 and 1986-1987) of an urban public high school. The study looked at four different classroom environments: a geometry class in which students used an intelligent tutoring system, a computer science class that included laboratory time for software design and development, classes on business applications of computers, and a computer laboratory that was available for students to use during their lunch break. Around 400 hours of observation data, in the form of field notes, were collected from these classrooms. In-depth interviews were conducted with 12 faculty members, and around 250 hours of interview data were collected from students in the study classrooms. Traditional content analysis procedures were applied to the interview data.

In the geometry class using the intelligent tutoring system, Schofield (1995) found changes in teacher practice and in student behavior. Teachers tended to devote more attention to lower achieving students as compared with the normal classroom situation where attention was more often directed toward higher achievers. Higher achievers were able to rely on the help provided by the computer software, and low achievers were less embarrassed to request help in a one-on-one interaction compared with the public nature of classroom discourse. The teacher's role shifted toward being a collaborator rather than an authoritative expert, with a simultaneous decrease in the time used to lecture. The teacher's assistance was more individualized in nature and was more frequently requested by students. Students experienced an increased level of competition and challenge (although this may have been due to the nature of the specific software application used) and a decreased fear of embarrassment. Furthermore, given the opportunity to interact with their peers, students often assisted one another.

Schofield (1995) concludes that

> the effect of computer usage is likely to depend on a plethora of factors including the kind of software used (e.g., drill and practice, simulations, networking, tutoring), the kind of students using the software, the social and physical context of the computer use, and prior classroom practices. (p. 61)

Indeed her findings regarding change in student behavior and teacher practice may be very particular to the specific software and set-up in this study. It would be necessary to look at various computer applications and different set-ups in order to generalize her observations.

Sandholtz, Ringstaff, and Dwyer (1997) report on ten years of experiences with the Apple Classrooms of Tomorrow (ACOT) initiative. ACOT was established in 1985 as a research and development collaboration among public schools, universities, research agencies, and Apple Computer. The intention was to investigate how routine use of technology by teachers and students would affect the nature of teaching and learning. Initially, the study began with one classroom in each of five schools. The schools were selected to represent a cross-section of the United States in terms of grade level, socioeconomic status, and community settings. The classrooms were provided with computers, printers, scanners, laser disc and video players, modems, CD/ROM drives, and software packages. Equipment was upgraded as the years passed, and the actual participants also changed as the study focused on different issues at different times. Participating teachers and students each received two computers, one for school and one for home. Teachers received training in basic technology use, and coordinators were funded to provide assistance in technical and instructional matters. Teachers were not directed as to how to use the technology because the researchers simply wanted to see what would happen when constant access to technology was available.

To evaluate the effects of access to this technology, teachers were asked to record audiotape journals of their experiences every few weeks and to write weekly reports on events in their classrooms. Researchers also tracked site correspondence among the project teachers. In the first few years, little change occurred in the nature of student learning tasks. However, teachers did interact differently with students, functioning more as guides and mentors and less as lecturers. Students cooperated and interacted more with each other. They did not appear to get bored with the technology over time. Project teachers also collaborated more, sharing experiences, ideas, and information. As time progressed, teachers teamed up and worked across disciplines. Schedules were altered to accommodate class projects, as was the physical set-up of the classroom. Additionally, new types of assessments were introduced, such as performance-based assessments and student portfolios.

While the amount of technology provided in the ACOT initiative might not be typical of a regular public school, this study does provide a realistic view of how teachers and students react spontaneously to the presence of technology. The evaluation itself resembles an ethnographic study more than a rigorous, controlled design, given that the specific interventions and the sites of experimentation changed during the ten years and no controls were tracked. Furthermore, the objectivity of the data might be questioned given the self-report nature and dependence on teachers as the sole source of information.

Perhaps the most important lesson from the ACOT study is the length of time it takes for changes to occur. Many technology initiatives last only a few years at most, and evaluations begin soon after an intervention's implementation. Under such circumstances, it is not surprising that many studies are inconclusive.

The most recent trend in evaluating the impact of technology moves away from assessing the effects of a specific application and toward assessing the impact of reform efforts in which technology plays a significant role. While some of these studies focus on the classroom as the treatment site, others look at initiatives affecting a number of schools or even an entire district. Many of these initiatives are funded through federal grant programs such as the United States Department of Education's Technology Innovation Challenge Grants or Technology Literacy Challenge Fund. Some of the studies specifically look for achievement outcomes such as increases in test-scores, while others focus more on changes occurring in the process of teaching and learning. A few combine both in an effort to identify how exactly the use of technology allows for altered outcomes.

Honey et al. (1999) report on observations and insights resulting from their research on technology initiatives in Union City, New Jersey. As part of a district-wide reform effort in 1993, Union City made substantial investments in technology resources for its schools. The student-to-computer ratio was reduced to four to one, and a fiber network was built to connect most of the instructional computers in the district as well as two public libraries, the city hall, and the local daycare center. Another initiative supplied certain teachers and students with networked computers at home and at school. Subsequently, district performance on standardized tests improved, most notably at the K-8 level. Students given home access to networked computers scored significantly better than their peers in writing and mathematics. While emphasizing that technology alone without the other aspects of school reform undertaken was unlikely to produce the changes observed, Honey et al. conclude that "deep and sustained access to technology has the potential to have a positive impact on both students' learning and on the school community's views of their students' capabilities" (p. 7).

Indeed, while such research may be realistic in the sense that it looks at technology use in the field, it is obviously impossible to attribute improved outcomes to the technology itself as opposed to other factors in the reform effort. The more wide-ranging the possible factors affecting outcomes, the more difficult it becomes to replicate a success story in other settings.

SRI International's evaluation of the Challenge 2000: Multimedia Project in San Mateo, CA, a Technology Innovation Challenge Grant project, provides a model for assessing changes in classroom processes as intermediate outcomes of technology use (Means & Golan, 1998; Penuel et al., 2000; Penuel & Means, 1999). The goals of the project were to engage students in their own learning and develop their skills of collaboration, decision-making, and complex problem-solving. To address these aims, the project introduced student-centered projects using multimedia in the classroom (e.g., audiocassette players, video cameras, digital editing, and web authoring tools) and provided relevant support to teachers on how to implement projects and use technology effectively. Multimedia technologies were not employed as stand-alone components, but as tools for use in the planning, development, and presentation of projects. These inputs were expected to change classroom processes and teaching practices and subsequently to lead to better student outcomes. The changes expected to occur included: students engaging in longer-term, more complex assignments; teachers acting as coaches and facilitators of student learning; students engaging in more small-group collaborative activities; students becoming more involved with external resources and paying more attention to external audiences.

For the Year 3 evaluation of the five-year project, evaluators developed an observation protocol for use in 19 classrooms across grade levels to examine variables including the dominant classroom activities, teacher and student roles, the nature of ongoing student work, and the level of student engagement. Means and Golan (1998) reported several significant differences between technology-using and non-technology-using classrooms. A classroom was classified as technology-using if, on average, students in the class used technology a half-hour or more a week for class work. In the former, students were more often observed working on long-term projects. Technology-using teachers were more likely to adopt a helping or monitoring role rather than using questioning as the primary means of relating to students. Students in technology-using classrooms were more likely to be constructing products: writing stories, making and recording observations, working through a set of problems, and so forth. Additionally, these students were more often observed collaborating in small groups.

One year later, 21 sixth and seventh grade classrooms were observed, once in the Fall and once in the Spring, each time within a three-week window. In addition to the variables studied in Year 3, new items were added to investigate the type of discourse taking place in the classroom. The evaluators wished to test the hypothesis that in project classrooms, more dialogic forms of discourse took place, whereas in comparison classrooms, the discourse was more monologic or teacher-controlled (Penuel et al., 2000). A second new hypothesis predicted that teachers in project classrooms would give students primary responsibility for their own learning by allocating more time for students to practice skills on their own. In comparison classrooms, teachers were expected to spend more time demonstrating skills or telling students what to do.

While in Year 3 observers recorded what was taking place in three 15-minute intervals throughout their observations, in Year 4 they recorded the different activities taking place across a 45-minute observation period for each classroom. The Year 4 observations again yielded a number of significant differences between the multimedia project classrooms and comparison classrooms. In project classrooms, students spent more time on activities that were long-term and cognitively challenging. Such "cognitive activities of design" (Penuel et al., 2000, p. 105) included deciding on the structure of a presentation; creating multiple representations, models, and analogies; arguing about or evaluating information; thinking about one's audience; and revising or editing work.

These stood in contrast to "teacher-directed solo activities" (p. 105), such as reading silently or listening to the teacher.

Differences in the role of the teacher were also observed. In project classrooms, students spent more time on activities independent of the teachers, either as individuals or in groups. The teachers acted more as coaches and facilitators, responding to student queries, providing help as needed, managing the organization of the task, and monitoring the students. In comparison classrooms, teachers were more often observed in directive activities such as questioning the students about the content, and explaining content or giving information.

Further differences were recorded in the amount of time spent in small-group activity, with students in project classrooms more often observed collaborating with peers than in comparison classrooms. Concomitantly, students in project classrooms were more often engaged in discussion with each other rather than with the teacher, that is, dialogic forms of discourse were more common. In comparison classrooms, the majority of observed discourse consisted of "instructional" (Penuel et al., 2000, p. 107) or known-answer questions and lecture-style or monologic discourse.

Finally, observers noted that project classroom students were more likely to be involved with external resources. Students in project classrooms used the Internet half of the observed time, whereas comparison classrooms made no use of the Internet at all. Additionally, students in project classrooms were observed discussing how audiences other than the teacher would view their work. This attention to external audiences was non-existent in the comparison classrooms.

These differences indicate that different activities are taking place in the two kinds of classrooms, with project classrooms more closely approximating what is currently believed to be a better, more student-centered learning environment. However, it is not yet clear whether students are indeed learning more content and skills, learning more efficiently, or improving their abilities to transfer such knowledge and skills to other situations. A Year 4 performance assessment task assigned to the students indicated that students from the multimedia project classrooms scored better only in the design aspects of creating a brochure. However, they did not score significantly better than comparison students on grasp of content or attention to external audiences. In addition, Stanford Achievement Test scores did not differ significantly for the two groups. This is not surprising, given that the project method does not directly aim to improve basic skills addressed by such standardized tests.

It is possible that a different performance task might pick up significant differences not addressed by the brochure exercise. This situation certainly underscores the difficulty in determining exactly what effects technology might have, even when the goals for its use are pre-specified. Designing an appropriate assessment to capture these effects is even more difficult. Moreover, it would be impossible to parse out the relative effects of the actual technology as opposed to other variables in a single such study. In this case, other potential factors affecting performance might be teacher quality, the project method, the drive toward the end-of-year Multimedia Fair, or the emphasis on small-group collaboration.

Self-report data from teachers involved in the project-based learning using multimedia initiative indicated a number of changes in teacher practice in the three years that the initiative had been operating. Not only did these teachers have students work on longer projects, but the students were more often allowed to select their own topics, work collaboratively, review and revise their own work, and make predictions about phenomena and investigate them. More expert teachers (with two or more years of experience implementing projects) and those working with three or more partner teachers were more likely to permit such student-led inquiry, suggesting the importance of peer support.

The teacher survey provided some insights as to why the multimedia projects helped students perform better. Students' greater inclination to collaborate meant that help was received from peers as well as the teacher. Additionally, students held each other accountable for completing tasks. Student motivation was higher because they were eager to use the technology, a phenomenon that could fade as technology use becomes standard in classrooms. Students were able to imagine an end product and were driven in learning what was necessary to achieve the goal. The public nature of their work, given that the whole class was able to view the screen-based products, may also have increased pressure to produce better products.

Detailed case studies of the development of two student projects provide some interesting examples of what the teacher did that led to some of the changes observed. One teacher consistently asked students questions about how an outside audience might perceive their work. He also frequently videotaped students collaborating and replayed the clips to the class so that they could identify helping and hindering actions. This video debriefing seemed to help the students regulate their own behavior in group activities. Both teachers in the case studies provided opportunities for students to learn how to critique their own work, a strategy that seems to have played an important part in motivating students to do better.

While the foregoing review of studies identifies many changes already observed occurring in the classroom as a result of technology use, McClintock (2000) reflects on the potential still to be realized. Based on experiences with various technology projects designed and implemented by the Institute of Learning Technologies (ILT), he suggests two major changes in educational practice that will occur as a result of digital technology use in the classroom, one regarding the nature of learning experiences and the second regarding access to resources.

First, McClintock (2000) hypothesizes a move away from teacher-led instruction and toward student-centered construction of knowledge. He argues that instruction as a pedagogical strategy persists primarily due to the constraints of communication between teachers and students: textbooks are the primary sources of information, curricula are pre-set and packaged into subject areas and lesson modules, and teaching methods are driven by competitive testing. Networked digital information and communication systems, McClintock predicts, hold the potential to remove constraints of communication, allowing students to direct their own learning, to interact more with each other and with sources beyond the teacher, and to engage in open-ended exploration of ideas and content. In such an environment, the teacher can shift his or her focus away from providing pre-established answers and toward asking "productive" (p. 2) questions. What is learned in the classroom no longer needs to be limited by the teacher's own knowledge or the information provided in a textbook.

From the perspective of education as communication, McClintock (2000) argues that it is difficult to compare the outcomes of education before and after the adoption of digital communications. He suggests that instead of conducting outcomes analysis, research should focus on documenting variations in processes of education based on different technologies. Specifically, he outlines the need to define how interactions change once students have control of the new information and communications technologies. Already, ILT projects have seen changes in communication patterns as students engage in web searches, on-line mentoring, and computer-mediated collaborative projects. Local communications are supplemented by long-distance activities that were previously impossible. Use of e-mail has also increased dialogue among students, parents, and teachers. Furthermore, digital technologies require a change in the nature of feedback to students on the quality of their work. With students more in charge of directing the products that result from their work, they need more continuous feedback on their progress and the ability to judge performance for themselves.

McClintock's (2000) second hypothesis predicts that, as networked digital communications become more ubiquitous, the kinds of resources that have heretofore been available only to those in higher education will be accessible to all. Whereas currently libraries and laboratories are too expensive to be provided to everyone, virtual access is both cheap and avoids many of the problems of security and safety associated with real access.

McClintock (2000) does, however, describe a number of impediments that are delaying the shift to student-centered education and universal access. While the provision of hardware and connectivity have been readily achieved on a widespread basis, effective use of the tools is lacking or at best limited to specific areas of the curriculum. One reason, McClintock suggests, is that teachers are short on time. Those who are inclined to use technology face the challenges of pre-set curriculum requirements and tests. Additionally, they must satisfy the habitual expectations of students, parents, administrators, the public, and other teachers. As a result, teachers need a great deal of time to rethink their practice in a manner that can effectively leverage the new technologies and yet conform to these existing structural requirements. McClintock does, however, predict that in the long term, the new media will allow for learning that is not limited by uniform standards.

Time is only one of the issues that McClintock (2000) identifies as responsible for stifling the effective use of technology. Mandating the provision and use of technology rather than responding to the needs and readiness of users has resulted in a mismanagement of resources. Consequently, many situations arise where computers sit unused in the classroom. Additionally, most initiatives focus excessively on the teacher rather than providing students with opportunities to drive their own learning. McClintock blames this problem on the paternalistic nature of social services that translates into a lack of confidence in children's ability to direct themselves competently. Indeed, McClintock hypothesizes that those technology initiatives primarily targeting students as the users will have a greater impact on learning than initiatives focusing efforts more at teachers (personal communication, February 9, 2000). In addition to providing access to networked digital communications to teachers and students within schools, McClintock

(2000) also suggests that the impact of technology would be maximized by extending access to the home and the community in general.

Based on the findings of the studies reviewed here, it is apparent that many changes have been documented in the classroom that are associated with various types of technology use. While some studies claim to link technology use to standardized achievement scores, others assess student performance on more complex tasks such as completion of projects. However, these studies consistently fail to address the mechanisms by which computer use might lead to the observed improvements. Often these studies occur in idealized situations so that the findings are not generalizable to the typical classroom situation. A different set of studies attempts to evaluate how classroom processes change in the presence of technology use. These findings provide the basis for explaining how technology might lead to improvements in the learning process. However, the need still exists for studies that trace the link from input to output via specific process changes. Areas in which further research is needed to evaluate the impact of technology in the classroom are outlined in the next section.

Areas for Further Research on the Impact of Computers in the Classroom

The foregoing review of the literature indicates a number of venues for further research, including implementation studies, classroom process studies, studies of outcomes, and cost-effectiveness analyses. Existing implementation studies commonly focus simply on documenting the progress made in following the planned elements of a technology initiative. Such studies would be more useful if, in addition, they attempted to identify those conditions that help or hinder the process of implementation. Such information is important if any intervention is to be successfully applied across treatment sites that differ in various respects ranging from geographical location to financial resources. As previously noted, Honey et al. (1999) have already called for a shift in the direction of research from assessing the impact of individual tools or inputs to looking at reforms as a package of inputs within a specific context. They argue that the conditions applying in any particular situation and the mix of changes undertaken simultaneously will affect the impact of any intervention. This suggests that a number of implementation studies would be useful comparing different classrooms, schools, or districts with similar access to technology. Differential adoption and effectiveness of the technology would be attributable to the different conditions existing in each treatment site. Variations might exist in factors such as school leadership qualities, teacher quality and professional development opportunities, characteristics of the school population, pedagogical methods, curriculum, mandatory tests, and mode of implementation, for example, top-down versus bottom up initiation.

Heinecke et al. (1999) suggest that evaluations of technology must take into account the "different phases of a school's integration of technology: purchasing and installing hardware and software, training teachers, integrating technology into the curriculum and instruction" (p. 6). Implementation studies should therefore be completed before any evaluation of effectiveness is undertaken. Furthermore, evaluation designs should be longitudinal and take into consideration changes in the sample population. In order to account for the level of background effects, comparison groups that are not exposed to technology should be tracked, or, alternatively, relevant comparison data could be obtained from existing national surveys.

Further studies to identify changes in the learning process associated with technology use would increase educators' and policymakers' understanding of how technology-based interventions actually lead to changes in student outcomes. With a knowledge of what is changing in terms of process, it would be easier to predict which outcomes should be expected to change and to design appropriate instruments to detect improvements or declines in outcomes. By linking the process changes to outcomes, those process changes leading to desirable outcomes could be identified and encouraged on a larger scale, taking into consideration any barriers to effective implementation.

The Penuel et al. (2000) study on how classroom processes have changed as a result of the introduction of student-centered projects using multimedia could be easily adapted to study the impact of many kinds of technology-related reforms on classroom processes. Indeed, if enough similar studies were conducted on initiatives that all involved the same technology component but different accompanying changes, it should be possible to identify which inputs were the most important in terms of leveraging the impact of the technology. For example, one could argue that in the Penuel et al. study, the important inputs were the project method, teacher training, multimedia tools, small group work, and year-end Multimedia fairs. A similar study on an initiative that omitted one of the inputs would allow for a measure of its importance. By dropping the multimedia element itself, an estimate of the importance of the technology per se could be made, provided that the nature of the projects does not change so dramatically as to render a comparison misleading.

With respect to studies measuring changes in outcomes associated with technology use, it is important to know whether the technology intervention aids students in learning content and also in learning skills that are transferable to various areas of study or activity. The aforementioned study of SSEs by Black and McClintock (1996) provides an excellent model in which students exposed to technology in one context are asked to complete an assessment task in a different context and their performance compared with that of a control group. This model could be adapted to assess the effectiveness of a variety of technological interventions, ideally sampling a larger number of students across a number of schools.

Studies of implementation, process changes, and impact on achievement outcomes are all necessary for policymakers and educators to assess the potential effectiveness of technology applications in the classroom. Finally, cost-effectiveness analyses could compare the impact of technology-based interventions with more conventional methods in order to determine where taxpayer money is best spent. This particular study focuses on one of these research areas, the assessment of process changes associated with computer use, in order to help fill one of the gaps identified in the literature.

From studies already conducted on process changes, a number of hypotheses emerge that could be relevant in any technology-rich classroom. These can be grouped into four major categories: increased collaboration and communication; a change in content and resources available; more individualized classroom experiences for students; and greater responsibility taken by students for their own education. Each of these categories is discussed further below with suggestions made about how the changes might lead to improved outcomes and proposals put forward as to how these ideas could be tested.

Increased Collaboration and Communication

A number of the hypotheses in the existing literature allude to greater interaction among students, between students and outside parties, and between teachers and parents when technology is available in the classroom. Within the classroom, it is questionable whether the technology per se is responsible for this observation or whether it is actually the project method employed in many of the classrooms where these observations were made. However, given the greater facility and decreased cost offered by e-mail and the Worldwide Web, as compared with traditional forms of communication, it is plausible that technology does indeed encourage communication with outside parties.

It would be necessary to test the relative effects of the project method versus technology per se by comparing classrooms similarly rich in technology but where some employed project methods and the others did not. It would seem evident that a technology-rich classroom that emphasized individual activities would be less collaborative than one employing group activities. It would be more interesting to discover whether a technology-rich classroom emphasizing individual activities was more or less collaborative than a technology-poor classroom similarly emphasizing individual activities. This would address questions raised by technology critics over the potentially negative effects of computer use on socialization.

If, indeed, technology-rich classrooms are more collaborative, the next question to be answered is whether this leads to greater achievement and why. It is possible that input from a wider range of parties, whether peers or outside experts, simply increases the knowledge and skill sets available to students beyond the limitations of any one teacher. It is also possible that the opportunity to collaborate provides greater motivation for students and that attitudinal changes could lead to better performance.

A Change in Content and Resources Available

Other hypotheses reflect a shift in classroom content as well as access to a wider range of resources. As mentioned above, many of the observed classrooms employed the project method. A relevant question here is whether the arrival of technology and the project method were deliberately coincidental or whether one led to the other. The ACOT studies (Sandholtz et al., 1997) imply that the availability of technology led teachers to adopt the project method. If this conclusion were substantiated by further studies, technology should be introduced only if the project method is considered desirable.

It is possible that learning environments employing both project methods and technology more closely approximate what graduates will be doing in the workplace so that this type of education provides better preparation for future employment. Longitudinal studies of students from various types of classrooms through college and employment could verify this assumption.

Giving students more input in deciding the content of their work may increase motivation, allowing personal interest to drive students toward a better product and performance. Having the opportunity to work on open-ended assignments with no single correct response may allow students to take greater risks knowing they will not simply get a right or wrong grade. Perhaps if such assignments were assessed on skills demonstrated as well as content, students might be more inspired to develop skills rather than simply regurgitate, remember or forget facts. Similarly, asking open-ended questions may require students to think more deeply about their responses or to connect the topic to personal experiences, interests, or former knowledge.

Access to a wider range of resources through technology would not alone ensure better student performance, as students must learn how to make good use of the information available. Studies looking for connections between availability of resources and student performance must also take into account how the resources are used in order to provide useful guidance for replication of the effect elsewhere.

More Individualized Classroom Experiences for Students

Another set of hypotheses points toward greater tailoring of education to fit individual student needs as well as interests. It is possible that when students are engaged with technology, the teacher is able to maximize his or her ability to help students by responding to individual or small group requests for help rather than offering it to the whole class. As a result, students may be better able to progress at their own pace. This might be especially important with respect to helping lower achievers. If high achievers do indeed require less attention in a technology-rich classroom, then efficiency may be improved, allowing the quality of instruction received to be raised for all.

By allowing more open-ended assignments, students may be better able to pursue their own interests, execute work using different tools, and demonstrate particular skills. Providing opportunities for students to critique their own work could raise students' awareness of the quality of their work. Allowing students more input with respect to the frequency and nature of feedback could improve the quality of advice received from teachers and peers.

Observations of classroom activities and teacher-student interactions allow an assessment of whether these types of changes actually occur. If technology-rich classrooms do provide for greater tailoring of instruction, it would eventually be necessary to demonstrate whether this leads to better student performance as might be expected.

Greater Responsibility Taken by Students for Their Own Education

Finally, it appears that some of the burden of responsibility for education has shifted from the teacher to the student in technology-rich classrooms. Students appear to take more initiative than those in low technology classrooms in asking for help and requesting feedback. Developing the ability to critique their work may be an important factor in helping students regulate their own performance. While it is possible again that the project method is responsible for much of this change, it may be the case that technology facilitates greater independence from the teacher by allowing broader access to information and alternative help. Developing appropriate indicators of student responsibility for work would allow a comparison of technology-rich classrooms with technology-poor classrooms in order to verify the development of this phenomenon.

All four of these areas of process change merit further study as potential means for improving classroom instruction and student performance. Understanding how the changes might lead to better student performance will increase the likelihood of successful wide-scale adoption of the relevant interventions. Any of these changes could theoretically be achieved without computers or other technology, and attempts to do so have clearly been made in the past. However, if technology provides an efficient means of achieving these ends, then policymakers and educators would certainly be provided with an incentive to continue and expand the presence of technology in the classroom.

For the purposes of this study, one of the four areas is scrutinized: the individualization of students' classroom experiences. The next chapter frames the research question and presents testable hypotheses derived from those existing in the literature regarding processes that might be expected to change in the classroom when computers are being used. Building on the strengths and weaknesses of past study designs and utilizing the findings to inform on the confounding factors that potentially obscure the ability to attribute effects to the technology inputs, an appropriate methodology for testing these hypotheses is developed.

Chapter III

RESEARCH METHODOLOGY

Rationale for the Research Design

The initial broad goal of this study was to establish whether and how initiatives to increase the presence of technology in the classroom have any positive impact on learning. A number of questions arose in determining how to narrow this question into a series of hypotheses and design a study to test them. These questions included: what kind of information would be of value to the policymakers and educators who are in a position to influence educational interventions; what should be the unit of focus among the choices of student, teacher, classroom, school, and so on; what practical constraints are likely to limit the possibilities for a study design; what outcomes should be measured, and how can they be captured.

As far as the major unit of study was concerned, it seemed clear that if the goal was to assess the impact of computer use on learning in the classroom, then the most accurate measure would be obtained by focusing on the students themselves. Certainly, there is valuable information to be reviewed at the school and teacher levels, but however well equipped a school may be and however well trained a teacher is in integrating technology into the curriculum, there is no guarantee that these factors translate into improved or altered student learning. A clear view of the learning process is best obtained directly from student outcomes.

Initially, it appeared that the best study design would involve setting up a true randomized experiment whereby some students were using computers in the classroom and some not. A suitable outcome measure could be identified or designed to help determine whether any difference arose that could be attributable to the use of computers. Indeed, Slavin (2002) makes the argument that nothing short of randomized or rigorously matched experiments is adequate to give policymakers reliable information regarding the effectiveness of educational interventions. However, the foregoing review of the literature and practical considerations leave this conclusion questionable.

Randomized experiments with pre-determined treatments may provide an accurate view of the impact of an intervention as delivered in carefully controlled circumstances, but the results are unlikely to reflect how interventions are actually delivered in typical classroom situations. Implementation studies invariably show that the intentions of policy initiatives rarely survive intact across the classroom door. The literature review indicated that numerous studies have already ascertained the potentially positive impact of computers in ideal situations. The need remains to determine whether this potential is being tapped in regular classroom environments. Rather than focusing the study on what policymakers would like to see happen, it appears more appropriate to focus on what is actually happening in the classroom. This implies the need for a field study approach. However, while a field study might provide more generalizable results than an idealized experiment, data collection practices must be developed to maximize consistency and reliability.

In addition to theoretical considerations, practical constraints were also considered in arriving at a study design. True randomized experimental research is extremely difficult to execute in public school classrooms. Various layers of bureaucracy must be petitioned to obtain permission for a school to participate in a study, and the layers increase as the research unit descends from the school level to classrooms, teachers, and students themselves. The net result is that arriving at a true random sample of any meaningful size is all but impossible. The lack of a random sample clearly introduces weaknesses on any study design and imposes the responsibility to consider confounding variables that would normally be washed out in a random sample. Additionally, analytical procedures must be followed to correct for lack of rigor in the sampling structure.

In order to execute a field study that could provide a realistic view of the impact of computers in the classroom and yet be rigorous enough to provide reliable results, a number of approaches were adopted. Firstly, the study aimed to include as many schools and classrooms as were practically manageable to study within a few months. Secondly, data were collected at several different levels: the school, the teacher, the classroom, and the students. This allowed a whole range of potential confounding factors to be accounted for. This strategy also allowed checks of one data source against another to assure reliability of conclusions. Thirdly, data on students were collected using both questionnaires and observations. The questionnaires, while potentially weaker on reliability because of their self-report nature, provided a larger sample size and a long-term view of what happens in the classroom. Observations provided first-hand data that were not subject to the problems of interpretation but had a smaller sample size and provided only a snapshot of the classroom environment. Fourthly, data collected were almost all quantitative in order to allow for statistical analysis. In particular, multilevel statistical procedures were used to provide extra rigor to the analysis. This procedure recognizes, for example, that students from the same classroom share certain inputs and therefore cannot be considered totally independent. More stringent tests of significance lend greater credibility to the findings than traditional, single-level analyses that are currently typical in educational research.

In considering suitable outcome measures for the study, it is clear that policymakers are most likely to pay attention to studies showing associations between educational interventions and test score changes. Indeed, the literature review indicated that several studies have attempted to link computer use with improvements in test scores. However, this approach is theoretically problematic. Firstly, most use of computers in the typical classroom, such as Internet research, is not designed to specifically address test scores or skills currently measured by tests. Computers are more often used as a tool for enhancing the execution of regular classroom assignments, for example, expanding research capabilities. Consequently, test scores are a weak and indirect measure of their impact. Secondly, any such study must be able to link computer use and test scores in a chronologically feasible time frame. It cannot be expected that computer use will have an immediate impact on test scores, and many educators argue that several years must elapse after implementation of classroom technology before looking for any change in achievement outcomes. This would imply that reliable conclusions regarding the impact of computer use on achievement scores could only be drawn by conducting longitudinal studies. Given these considerations, it would seem more important currently to determine how computers might be making a difference in the learning process rather than jumping directly to measure achievement outcomes. By focusing on process changes, it will eventually become possible to explain the mechanisms by which computers might affect achievement outcomes.

The literature review identified numerous changes occurring in the learning process when computers are used in the classroom, and these were grouped and summarized at the end of Chapter II into the following categories: increased collaboration and communication; a change in content and resources available; more individualized classroom experiences for students; and greater responsibility taken by students for their own education. These were used as the basis for developing the research question and specific outcome measures for this study.

Research Question

The overarching research question addressed by this study was whether students using computers in the classroom receive instruction that is more tailored to fit individual student needs and interests than those not using computers. A number of observations from the literature on the impact of computer use in the classroom support this observation: teachers act more as coaches and facilitators than as directors, responding to student questions and offering help to individuals or small groups when needed rather than questioning the students as a class about content and demonstrating skills or providing information; students make more frequent requests for individualized help; assignments are more open-ended with no one correct response; students are provided with opportunities to develop the ability to critique their own work; students have greater influence on the type and frequency of feedback; teachers spend more time with lower-achieving students while higher achievers are able to progress with less help.

In order to answer the research question, this study aimed to test a number of hypotheses, derived from and expanding upon these phenomena reported in the literature. The following changes in the classroom learning environment were expected when students were using computers:

Hypotheses

I. Students receive more individual attention from the teacher.

II. Verbal interactions are more frequent and of greater duration.

III. Individual or small group interactions as opposed to large group interactions are more frequent.

IV. Feedback is more frequent and varied in terms of origin.

V. Tasks assigned to students across the class are less uniform.

VI. Students have more choice in assignments worked on in class.

VII. Students work more often independently or in small groups as opposed to working as a whole class.

VIII. Students work more often on open-ended assignments such as projects.

IX. A greater variety of resources are used by students.

X. Resources are more often used spontaneously rather than in response to teacher direction.

Objectives of the Study

In order to test the above hypotheses, a number of corresponding measurable indicators of individualized instruction were developed. The objectives of this research study were to establish whether the following indicators changed with increasing levels of computer use by students:

1. students' reported level of individual attention received from the teacher for academic purposes;
2. the frequency, length, and content of verbal interactions between teacher and students and among students;
3. the grouping in which interactions occurred;
4. the frequency, nature, and origin of feedback received by students on their academic work;
5. the types and lengths of assignments worked on by students;
6. the grouping in which the students work;
7. the degree of variation in assignments across the classroom;
8. the students' level of choice in selecting assignments to work on;
9. the number of resources used by students for completing educational assignments;
10. the number of resources used at the students' own initiative.

Rationale for Methods

Most of the proposed hypotheses regarding expected changes in the classroom learning environment required testing through quantitative measurements such as frequency of events and duration. As Good and Brophy (1987) point out, quantitative studies allow for collection of a narrow range of information in many classrooms and can identify general patterns of behavior. Similar types of information have been collected by researchers using a variety of observation instruments, ranging from simple frequency counts to complex scales (Simon & Boyer, 1967). Bakeman and Gottman (1997) note that "nonsequential systematic observation can be used to answer questions about how individuals distribute their time among various activities, or distribute their utterances among different utterance categories" (p. 13).

The information could also be collected using questionnaires. However, while questionnaires might facilitate a study with a larger sample size, the accuracy of responses to such questions would be expected to be significantly lower than those obtained by direct observation. In the case of observations, the observers are trained to look first-hand for specific phenomena. Objectivity and consistency across the data collection sample are expected to be high. With questionnaires, the study subjects are providing self-report data with the obvious implications of subjectivity and variability in the interpretation of questions. To some extent, there is a compromise to be made between expanding the sample size and assuring the reliability of the data collected.

Good and Brophy (1987) describe the advantages and disadvantages of using observation scales in classrooms. By measuring actual numbers of behaviors per unit of time, comparisons can be made among students or across classes. However, use of observation scales often requires more observer training than methods such as questionnaires or simple frequency counts. Additionally, while an observation scale captures the behaviors in question, no information is captured regarding other activities in the classroom. Observations provide focused, snapshot images of classroom activities, whereas questionnaires can present a broader picture reflecting the classroom situation over an extended period of time.

While the required information could be collected from teachers, Good and Brophy (1987) emphasize that "the key to looking in classrooms is student response" (p. 71). Given the question of whether students experience more individualized instruction when using computers, it would seem particularly appropriate that this study should focus on the experiences of the student. However, the collection of similar data from teachers allows for verification of student-reported information.

In an attempt to balance the advantages and disadvantages of observation versus questionnaire methods and teacher versus student focus, this study collected data on the classroom environment using three separate instruments: a teacher questionnaire, a student questionnaire and a student observation schedule. The instruments complemented each other by overlapping in some respects to allow for verification of the data. In other respects, the instruments diverged in order to provide information that could only practically be collected by that particular method or to add detail to some particular facet under study.

Confounding Factors

In determining an appropriate study design for conducting observations of students and collecting questionnaire data from them, a number of confounding factors must be taken into consideration. Given the huge number of variables associated with any social study situation, certain variables need to be controlled for, if possible, in the study design. For example, classrooms involved could be of similar grade levels and subject and from schools with similar demographic composition and general funding levels. In order to minimize noise from variation, this study only included public middle schools in Manhattan, and participants were teachers of sixth, seventh, or eighth grade science and their respective students. Other potential sources of variation are reviewed below.

1. *Availability and use of resources*: Resources available in the classroom inevitably vary, including the teacher/student ratio, number of computers accessible,

number of Internet connections, and so on. In this study, a record of the numbers of computers, students, and Internet connections in the classrooms allowed for these to be set up as control variables in data analysis. Becker, Ravitz, and Wong (1999) specifically demonstrate the connection between computer availability in the classroom and frequency of use. Technological resources were only counted in this study if the equipment was in working order.

2. *Teacher's philosophy*: Constructivist teachers might naturally be more likely to assign open-ended tasks according to individual student needs and interests, to provide more opportunities for personal interaction and a variety of forms of feedback. Additionally, Ravitz and Becker (2000) and Ravitz and Wong (2000) indicate that more constructivist teachers use computers more in classroom instruction. It was therefore desirable to employ some measure of the teacher's philosophy as a control variable in the data analysis. In this study, the teacher questionnaire included a section specifically addressing the teacher's philosophy and allowed a score to be assigned to each teacher, placing them on a continuum from traditional through constructivist.

3. *Student capabilities*: It is possible that when students of different capabilities are assigned different types of tasks, they vary in their use of resources and engage in different interactions with peers and teachers. To help minimize the contribution of this factor, the teachers were asked to select classes for study participation that they considered "average" in achievement level. Of course, "average" achievers in one school could be very different from those in another, so that individual test scores were collected for each participating student to be included as control variables in data analysis.

4. *Scheduling*: Different schools schedule classes of different lengths, and some have double periods for science whereas other only have single periods. Classes that extend longer are more likely to allow for activities such as on-line research or project work so that scheduling could clearly act as a confounding factor. Both frequency of class meetings per week and total time spent in science class per week were collected for use as control variables in data analysis.

5. *Teacher versatility with technology*: Teachers with more computer experience either on a personal level or through professional development are likely to have changed their pedagogy more to incorporate technological resources. As with teacher philosophy, the teacher questionnaire addressed issues of the teacher's attitude toward computers, extent of computer use in and out of the classroom, technology skills, and extent of technology professional development received in order to account for the impact of these factors in data analysis.

6. *Student versatility with technology*: Students who have had more experience using computers either at home or at school are likely to behave differently with respect to computer use in completing schoolwork. The student questionnaire was designed to allow a score to be assigned to each student accounting for computer use and skills so that these factors could be controlled for in data analysis.

7. *Curriculum and teaching practices*: Teachers' classroom practices will vary according to philosophy, training, and the requirements of the curriculum in use or standards set by the local district, state, or other governing body. Frequency with which various teaching strategies were employed in the classroom was addressed in the teacher questionnaire. Teachers were also specifically asked about the curriculum being followed

(e.g., Life, Earth, or Physical Science) and standardized tests to be taken by the students in their classes.

8. *Length of time technology has been used in the classroom*: Teachers who have had more experience using computers and other technology in the science class are likely to have changed their practices more than those teachers with less experience. Similarly, students who have used technology extensively in school are likely to respond differently to its presence than students who are new to the experience. The questionnaires for both teachers and students addressed length of experience with computers in the classroom.

Beyond these structural issues, any type of data collection in schools will be affected by other factors. The teacher may generally act differently in the classroom when an observer is present and, more specifically, may interact differently with a student being observed compared with a student not being observed. The students' behavior is also likely to be affected by the act of being observed. These factors cannot be avoided in such a study and would be hard to control for. However, both students using computers and those not using computers were observed so that all study participants were subject to similar conditions in this respect.

Study Design and Sampling

Overview of Study Design

The study collected data at three different levels, creating a nested design:

Level 1 – Students.

Questionnaires: Six hundred seventy-three students from sixth through eighth grade public school science classrooms in Manhattan responded to a four-page questionnaire asking about the respondent's demographics and use of computers in general (frequency of use, location of computers used, kinds of activities performed with computers) and specifically in science class at school. Finally, the students were asked a number of questions addressing the learning environment in the science classroom.

Observations: One hundred ninety-three of the 673 respondents were observed in the science classroom for 30 minutes each. The observation instrument collected data regarding the frequency and nature of the observed student's interactions, the frequency and source of academic feedback, the type and duration of activities engaged in, and the kinds of resources used.

Level 2 – Teachers. These students were grouped in classrooms taught by 50 different science teachers. Each of the teachers completed an extensive questionnaire regarding their teaching philosophy and practices, their skill with technology and use of it, as well as demographic data. Teachers were asked to select one class for inclusion in the study (although one teacher requested that both her eighth grade classes be included). Some additional data were collected about each selected class and the classroom(s) in which they met for science, for example, meeting schedules and technology resources available in the classroom.

Level 3 – Schools. The 50 teachers taught at 20 different public schools in Manhattan. A school data sheet was collected with demographic data for each participating school plus some information about technology initiatives in the school and technology support.

The school level data were collected first, followed by the teacher/classroom data, student questionnaires, and finally the student observations. Methods employed for collection of each data set are described in detail below.

School Sampling and Recruitment Methods

The study included a non-random sample of 20 public schools in Manhattan serving middle school students (Grades 6, 7, or 8), located in Community Districts 1 through 6. Districts 1, 2, 4, and 6 were each represented by only one school, whereas Districts 3 and 4 were each represented by eight schools. This distribution does not allow for valid comparisons to be made across districts so that for the purposes of analysis, district will be treated as a fixed effect.

Only schools that served students in Grades 7 and 8 were included in the study. Some of these served lower or higher grades in addition, but schools serving students only up to sixth grade, that is, elementary schools, were not included in order to avoid the differences in nature between elementary and middle schools. According to the New York City Department of Education's Division of Assessment and Accountability website (http://www.nycenet.edu/daa/01asr/), there are 59 public schools in Manhattan that qualify under these criteria. However, it should be noted that District 4 only lists 4 middle schools, while in reality these have been restructured into several smaller schools, bringing the actual number to 17 according to a count by the District 4 Office Secretary. A more accurate number for Manhattan schools serving middle school students is therefore 72. The sample of 20 schools represents 28% of these schools.

Once New York City Board of Education (now Department of Education) approval had been received to conduct this study with sixth through eighth grade students, a list of schools containing these grade levels in each of the six Manhattan community school districts was obtained either from district websites or from district offices. The study was limited to Manhattan for practical reasons to ensure that a relatively large amount of data could be collected within one academic year.

The number of schools that participated depended on the approval of the district superintendent and often also the district technology offices. District administrations varied in their willingness to allow researchers into their schools as well as in their interest in research about technology in the classroom. Generally, they tended to direct researchers away from schools that were in the process of restructuring or otherwise in disarray. Each district varied in their requirements for obtaining approval to approach school principals regarding participation in the study. In three cases, the district technology officer suggested schools for participation. Once school principals had agreed, the superintendent's approval was given. In one case, the principal had to express an interest in the study before the district superintendent would give approval. In this case, potential schools were suggested by a professional familiar with the district (a district science coordinator), and initial contact with the principals was mediated through the district technology coordinator. Two districts required permission to be given by the deputy superintendent before the schools could be approached. In one of these cases, a list was submitted for pre-approval based on suggestions from a district staff developer. In the other case, a list was compiled based on interest expressed by principals at the district Middle Schools Fair.

Even once district approval was obtained, each principal's approval was required. Some refused because they felt their teachers were already overburdened with responsibilities and did not need further distractions. Once the principal had agreed, one or more of the science teachers also had to agree to participate in the study. As a result of these externally imposed limitations on the study design, the final sample of schools cannot claim to be a completely fair representation of public middle schools in Manhattan.

Collection of School Level Data

Data collected from each school included: total enrollment and distribution of students across grade levels served; gender balance and ethnic distribution of students; percent of students classified as receiving free lunch; percent of Special Education students and English Language Learners (ELLs); and percent of eighth graders meeting state standards on the English Language Arts (ELA) test and on the Grade 8 State Mathematics Test. Additionally, the number of teachers in the school was noted and inquiries made regarding the school's technology support resources and participation in technology initiatives.

These school data were collected from various sources. Each school was asked to complete a School Data Sheet (see Appendix A). This request was addressed to the principal or another administrator in the school. Some of the schools made their most recent Comprehensive Education Plan (CEP) available, which provides the Board/ Department of Education with data about the school's academic programs, goals, and current status. Additionally the 1999-2000 Annual School Reports were reviewed. These reports are compiled by the Division of Assessment and Accountability (DAA) and are publicly available on the Worldwide Web (http://www.nycenet.edu/daa/01asr/). The DAA states that it obtains its data from central databases and school principals. In some cases, the district office was contacted for information that could not otherwise be obtained.

It must be noted that there were frequent discrepancies in the various sources for many of the variables, some arising due to confusions when restructuring of a school had recently occurred and others for apparently unexplainable reasons. In these cases, judgment was exercised in determining which figures were most reliable. Free lunch statistics seemed particularly unreliable as a measure of the poverty level of the school population given the inconsistency between the principals' claims and the Annual School Report data. Even from mere observation, it seemed incongruous that some schools that appeared to be serving a significant number of wealthier families still reported a high percentage of free lunch.

Problems also arose with scores for the Grade 8 English Language Arts and Mathematics Tests. For example, in some cases, district level reports were based on the overall performance of a school that had actually been restructured into several smaller schools. Individual school principals provided scores only for their own students that could be quite different from the overall performance level.

Sample School Characteristics

The sample size for all reported school statistics is 20, as there were no missing school data. The data were collected using a School Data Sheet (see Appendix A). Schools varied in size from 120 students to 1,322 students, with a mean of 487. The number of teachers varied from 7 to 82, with a mean of 34.05. The ratio of students to teachers ranged from 9.16 to 20.63, with a mean of 14.94. Eleven of the schools served

Grades 6-8, five served Grades 7-8, two served Grades 6-9, one served Grades 5-8, and one served Grades 7-12.

Table 1 compares demographics of the sample schools with those of city schools as a whole based on the DAA's 1999-2000 Annual School Reports. The comparison indicates that the school sample, compared with city schools as a whole, somewhat overrepresents girls, students receiving free lunch, Hispanics, and students

Table 1

Comparison of Sample School Demographics with City Schools as a Whole

Measure	Ave. % for sample schools	Ave. % for city schools
Girls	54.1	49.0
Boys	45.9	51.0
Free lunch	78.9	71.9
ELLs	8.4	14.0
Special Education*	14.1	14.0
African-Americans	35.1	34.6
Hispanic	49.4	37.3
White	9.7	16.5
Asian and other	5.8	11.6
Grade 8 Math	31.8	22.6
Grade 8 ELA	41.0	32.6

*Both full-time and part-time Special Education students included.

Note. ELLs = English Language Learners; Grade 8 Math = percent of students meeting state standards on Grade 8 Mathematics tests; Grade 8 ELA = percent of students meeting state standards on Grade 8 English Language Arts test.

meeting state standards in Mathematics and English Language Arts (ELA). Groups underrepresented at this level are boys, English Language Learners (ELLs), Whites, Asians, and Others. Female overrepresentation may be explained by the inclusion of one all-girls school in the sample. As noted previously, the free-lunch statistics are unreliable, as principals tended to report higher levels of free lunch in their schools than did their district offices. The higher test scores of the sample schools are not surprising given the aforementioned tendency of districts to steer researchers away from failing schools. The overrepresentation of Hispanics is due to the geographical distribution of the sample schools. District 4 has a high percentage of Hispanic students (60.9% compared with the average of 39% for the City as a whole), and 8 of the 20 schools studied were in this district. The underrepresentation of ELLs may also be due to district office screening of schools allowed to participate. As will be seen later in the student questionnaire sample statistics, some of these trends persisted at the student level, while others changed.

With respect to technology initiatives, all schools in the study benefited from Project Smart Schools and Project Connect. Project Smart Schools was a citywide Board of Education initiative that placed four computers in each middle school classroom. Project Connect followed this up by connecting these computers to the Internet. (See Department of Education website for more details: http://www.nycenet.edu/oit/pssguide.htm).

Eighty-five percent of the schools benefited from between one and four additional technology initiatives. The mean number of additional initiatives for the whole sample was 2.05 per school. Funding sources included: federal programs, the New York City Central Board of Education, Community District offices, City Council Grants, corporations, and not-for-profit organizations. Forty-five percent (9) of the schools were involved with a Federal Technology Innovation Challenge Grant, a federally sponsored incentive program aiming to encourage the development of innovative uses of technology in K-12 education. (See United States Department of Education's website: http://www.ed.gov/Technology/challenge/index.html).

Only 7 of the 20 schools had one or more staff members dedicated to technology support. The other 13 schools assigned the responsibility to a teacher or administrator.

Recruitment of Teacher Sample

The study included 50 middle school science teachers distributed across the 20 schools. In each participating school, all Grade 6-8 science teachers were invited to participate in the study. In some schools, the principal introduced the researcher to the science teachers. In many cases, the researcher was invited to a science staff meeting to talk about the purpose and methods of the study and invite participation. In a few instances, one teacher who was supportive of the study introduced the researcher to other science teachers. In one case, the district science coordinator contacted the teachers first.

At the initial meeting with the teachers, the researcher explained that the study aimed to detect any differences in the teaching and learning process that might occur when computers are used in the science classroom. It was stressed that the study needed to involve students using technology and those who were not and that the students' classroom experiences were the main focus of the study. It was also stressed that there was no presumption that the use of technology was either good or bad.

Between one and six teachers agreed to participate from each school, with a mean of 2.5 per school. The others refused for various reasons. For example, some thought the distraction would be too great or that they would have to do too much extra work. Others felt their students were too poorly behaved to participate. No doubt some simply did not wish to have a stranger observing students in their classroom.

Collection of Teacher/Classroom Data

Each teacher who agreed to participate in the study was given an extensive Teacher Questionnaire (see Appendix B) covering teaching philosophy, attitude toward technology, technology skills, use of computers in general and specifically with students in the science class, classroom teaching practices, and demographic information. The teachers were given the questionnaire at the initial meeting if they agreed to participate in the study. They completed the questionnaires in their own time (reported time taken to complete the questionnaire ranged from 20 minutes to one hour) and returned them to the researcher. Any missed questions or unclear answers were completed or verified by the researcher at subsequent visits to the relevant teacher's classroom or via e-mail so that this dataset eventually had no missing data.

Each teacher was asked to select one of his/her Grade 6, 7, or 8 classes to participate in the study. They were asked to choose a class they considered the most representative of the classes they taught, that is, neither a model class nor the worst class in terms of behavior or performance. An additional information sheet was attached to the Teacher Questionnaire so that the teacher could provide specifics of the class selected, including the class label, grade level, type of class (regular, honors, accelerated, bilingual, special education, etc.), the number of students in the class, meeting schedule, and location. A section was included for the teacher to provide contact information (telephone, facsimile, e-mail address, etc.) so that the researcher could schedule dates for observing students.

Some additional information regarding the classroom was collected by the observers on the observation instrument (see Appendix C), including the number of working computers, Internet connections, and printers in the classroom.

Sample Teacher Characteristics

Characteristics of the 50 teachers participating in the study were obtained through the teacher questionnaires (see Appendix B). The sample size is 50 for all reported items as there were no missing teacher data.

Forty-two percent of the teachers were male and 58% female. Fifty percent of the teachers were White, 24% Latino, 12% African-American, and 14% Asian-American or other. Teacher age varied from 21 years to 57 years, with a mean age of 37.06 years. Participating teachers were spread quite evenly along the spectrum of highest level of education achieved, with approximately one quarter of the teachers having a bachelor's degree, one quarter a master's degree, one quarter a master's degree plus 30 credits, and one quarter a master's degree plus 45 credits. The teachers in the sample had been teaching for between a few months and 35 years, with a mean of 9.2 years. Length of time teaching at the teacher's current school varied between a few months to 24 years, with a mean of 6 years.

Sixty percent of the teachers taught more than one grade level. Twenty-one teachers taught sixth grade students, 34 taught seventh grade students, and 35 taught eighth grade students. Many teachers taught one or more subjects in addition to science. For example, 30% also taught math.

Other issues addressed by the teacher questionnaire specifically to provide data relevant to technology use in the classroom are reported in Appendix D. These topics include teaching philosophy, teaching practices, attitude toward technology, technology skills, and use of computers in general and specifically with students in the science class.

Sample Classroom Characteristics

Each of the 50 teachers chose one class section to participate in the study, except for one teacher who had two classes participate, resulting in a total of 51 different classes. Sample size was 51 for the all classroom statistics, as there were no missing classroom data.

Of the 51 classrooms, 16% of the classes were Grade 6 only, 32% were Grade 7 only, 34% were Grade 8 only, and the remaining 18% were a combination of grade levels. Between 3 and 28 students from each class completed and returned student questionnaires, with a mean of 13.2 students per class.

The curriculum followed in the 51 classrooms was fairly evenly distributed among Life Science, Earth Science, Physical Science, and a combination of two or more of these. A few classes followed a different curriculum, for example, an environmental science curriculum. Fifty-six and nine-tenths percent of the classes were required to take a standardized test in science during the study year. Sixty-four and seven-tenths percent of the classes were regular track, 15.7% were accelerated or honors, 13.7% were bilingual, and the remaining 6% were Special Education, elective, or transitional classes.

The classes met for science for a range of 90 to 300 minutes per week, with a mean of 211 minutes. They met between 1 and 5 times a week, with a mean of 3.75 times per week. Class size ranged from 7 to 36 students, with a mean of 27 students.

Student Data Collection

Once a science teacher had returned the Teacher Questionnaire and Information Sheet, the researcher delivered envelopes for the selected class containing the Student Questionnaire and various consent forms (see Appendix E) to be signed by the students and their parents/guardians. In some cases, the teacher explained the study to the students, and in others, the teacher invited the researcher into the classroom to explain it. The consent forms were sent home with the students for completion, and once returned to the teacher, the questionnaires were filled out, either in class or in the student's own time, and returned to the researcher.

Six hundred seventy-three of a possible 1,377 students in the designated classes responded to the four-page Student Questionnaire, resulting in a 48.9% response rate. The demographic information presented below addresses biases in the sample. According to statistics obtained from the New York City Department of Education's DAA website, there are a total of 28,387 students in Grades 6-8 in Manhattan, so that the sample represents 2.4% of students in these grades.

Beyond establishing the respondent's demographics, the questionnaire addressed use of computers in general (frequency of use, location of computers used, kinds of activities performed with computers) and specifically in science class at school. Finally, the students were asked a number of questions addressing the learning environment in the science classroom. Three questions asked how the science class compared to other classes with respect to: degree of individual attention received from the teacher for academic purposes; amount of interaction among peers for academic purposes, and amount of feedback received on work. The remaining three questions asked about the amount of choice available in assignments to be worked on, the degree of uniformity of assignments across students, and the amount of choice in resources to be used. Results for these sections are summarized in Appendix F.

Sample Student Characteristics

Of the 673 students participating in the study, 55.1% were female and 44.9% were male. Age ranged from 10 years to 16 years, with a mean of 12.5 years. Twenty-three and two-tenths percent of the student sample was in Grade 6, 34.3% was in Grade 7, and 42.5% in Grade 8. Table 2 compares the racial make-up of the sample to that of New York City Schools as a whole (as reported by the New York City Department of Education's DAA Annual School Reports websites).

Table 2

Comparison of Racial Breakdown of Student Sample and New York City (NYC) School Students as a Whole

Race	% of study sample	% of NYC school population
White	15.0	16.5
Black	17.5	34.6
Hispanic	51.0	37.3
Asian and Other	16.5	11.6

Hispanics are overrepresented compared to City Schools, whereas Blacks are underrepresented. One reason for this is that 8 of the 20 schools participating in the study were from District 4, which has a high Hispanic student population. The overrepresentation of Asian-Americans may be due to a relatively high response rate from this ethnic group.

Socioeconomic status was addressed through two indicators, mobility and parental education. A measure of student mobility was obtained by asking students how many schools they had attended since kindergarten. The number of schools attended ranged from 1 to 15, with a mean of 2.81 (N = 672). Students were asked to indicate their mother's highest level of education (N = 633) and their father's highest level of education (N = 547). Thirty-two and two-tenths percent of the students had mothers who had earned a four-year college or higher degree, 27.8% had mothers who had attended some college or completed a two-year degree, and 2.4% had mothers who had attended vocational, trade, or business schools. The remaining 37.6% of students indicated that their mothers had attended school to some degree, with the highest level being a high school diploma or General Equivalency Diploma. Education levels of the students' fathers were similar overall to students' mothers.

In order to assess the achievement levels of the sample students, four different academic scores were collected: latest quarter's science grade ranged from 50% to 100%, with a mean of 79.46% (N = 671); latest GPA reported ranged from 53.41% to 99.20%, with a mean of 79.88% (N = 667); latest standardized reading score ranged from 1 to 4, with a mean of 2.60 (N = 612); latest standardized math score ranged from 1 to 4, with a mean of 2.46 (N = 625). (Standardized math and reading scores have a minimum possible score of 1 and a maximum possible score of 4.) Scores were unavailable for students who had recently moved schools or who had missed tests. Table 3 compares scores for sample students on standardized tests with scores for New York City School students as a whole, as reported on the DAA's school reports websites. While the full range of academic achievement is represented by the study participants, the average level is higher than that for students in City schools as a whole. This is most likely due to the fact that districts would not allow failing schools to be invited into the study. Additionally, it is less likely that students with low reading proficiency would respond to a written questionnaire.

Table 3

Comparison of Performance on Standardized Tests between Sample Students and New York City Students Overall

Comparison Measure	% of Sample	% of NYC Students
Reading: students meeting state standards	51.8	37.0
Reading: students far below state standards	7.6	18.5
Math: students meeting state standards	42.5	25.8
Math: students far below state standards	19.9	38.8

Selection of Students for Observation

Of the 673 students who responded to the questionnaire, 193 were selected for observation. A minimum of 3 students was selected from each classroom. It should be noted that classrooms where technology was used more were over-sampled in order to provide an overall sample in which roughly half the students were using computers during observation and the other half not. The use of multilevel statistics to analyze the data helps eliminate some of the bias introduced by such over-sampling.

A number of criteria applied in the selection of students to observe. The students had to indicate that they did not object to being observed, backed by parental consent. Within this group, the researcher avoided students with very high or low achievement scores and with very high or low technology skill scores in order to minimize the impact of these factors on the outcomes under investigation. These measures were nevertheless retained for control purposes in data analysis.

Characteristics of Student Observation Sub-sample

Forty-eight and two-tenths percent of the 191 observations deemed valid were of male students, and 51.8% were of females. Students observed ranged from 11 to 15 years of age, with a mean of 12.53 years. Nineteen and four-tenths percent were in Grade 6, 37.7% in Grade 7, and 42.9% in Grade 8. There were fewer students in Grade 6 than in the higher grades because in some districts Grade 6 is incorporated into the elementary schools rather than being part of the middle school, so that the pool of sixth graders in the study was smaller than for Grades 7 and 8.

The racial distribution of students observed is indicated in Table 4. Comparing observed students to the average racial distribution in New York City schools, Latino students were overrepresented in the observation sub-sample, as was the case for the overall student sample. This reflects the fact that Latino teachers in the study (who often taught Latino students) displayed a greater tendency to use computers in the classroom than other teachers, so students in their classrooms were observed more often. Asian-American/Other students were also overrepresented, reflecting their overrepresentation in the questionnaire dataset. Eighty-six and four-tenths percent of the students observed spoke English throughout the observation. Two and six-tenths percent spoke only Spanish, and the remaining 11% spoke a mixture of English and Spanish.

Table 4

Racial Distribution of Students Observed Compared with Average for New York City Schools

Student's Race	% of students observed	Average % for city schools
White	12.0	16.5
Latino	52.4	37.3
African-American	19.9	34.6
Asian-American/Other	15.7	11.6
Total	100.0	100.0

Thirty-five and one-tenth percent of the observations were of students being taught by a male teacher, and 64.9% were in classrooms being taught by a female teacher. This reflects the fact that more female than male teachers in the study had students use computers in the science class. Forty-three and five-tenths percent of the observations were conducted in classrooms of White teachers, 29.3% in classrooms of Latino teachers, 15.2% in classrooms of African-American teachers, and the remaining 12% in classrooms of Asian-American or other teachers.

Fifty-six and five-tenths percent of the observed students used a computer for less than half the time observed (i.e., less than 15 minutes), whereas 43.5% of them used a computer for more than 15 minutes. Computer use across all students observed ranged from 0 to 30 minutes, with a mean of approximately 12.5 minutes, skewness of .29, and kurtosis of −1.85. The observer deliberately set out to observe roughly half the students using a computer and half not. In this respect the data reported from the observations should not be used to generalize frequency of computer use across all classrooms.

Characteristics of the Observation Classrooms

Most observations took place in a classroom (85.3%), with a few in a computer laboratory (6.3%) and a few in a science laboratory (7.9%). One class spent time in both the classroom and the computer laboratory. Fifty-seven and six-tenths percent of the observations took place in the morning, and 42.4% took place in the afternoon. The number of students physically present in the classroom during observations ranged from 6 to 45, with a mean of 23.11, skewness of -.19, and kurtosis of .71.

A variety of class types was observed. Sixty and seven-tenths percent of the observations took place in regular track classrooms, 15.7% were in accelerated/honors classrooms, 17.8% were in bilingual classrooms, and the remaining 5.7% were in special education, elective, or transitional classes.

Thirty-eight and seven-tenths percent of the observations took place when the classroom as a whole was working on projects. Twenty and nine-tenths percent of the observations took place when the classroom as a whole was engaged in laboratory work. Classes ranged from 40 to 150 minutes in length, with a mean of 62.2 minutes.

The number of students in the classroom using a computer ranged from 0 to 45, with a mean of 5.34. The number of working computers available per classroom ranged from 0 to 57, with a mean of 9.15, skewness of 2.03, and kurtosis of 3.16. Average computer availability was calculated for each teacher, with most teachers having four or fewer computers in the classroom (see Table 5).

Table 5

Average Computer Availability for Teachers

Average computer availability	% of teachers
0	16.0
1-4	54.0
5-20	22.0
20 or more	8.0

The number of Internet connections ranged from 0 to 57, with a mean of 7.75. The number of Macintosh computers available ranged from 0 to 36, with a mean of 4.89. The number of PC's available ranged from 0 to 35, with a mean of 5.48. The number of laptops available ranged from 0 to 30, with a mean of 3.79. The number of desktops available ranged from 0 to 36, with a mean of 5.37. The number of printers available ranged from 0 to 7, with a mean of 1.13.

Observation Methods

The number of valid observations per classroom varied depending on ease of accessibility and whether or not technology was used. Each of the study classrooms was observed between 3 and 11 times with a mean of 3.82 (one classroom only had 2 valid observations after 1 had to be discarded). Classrooms in which computers were used regularly were observed more often in order to balance the number of observations between students using computers and those not. Additionally, because of the variable number of teachers participating from each school (between 1 and 6 per school), the number of observations per school ranged from 3 to 25, with a mean of 9.55. This bias in number of observations per classroom and school is exactly the type of design issue that highlights the need for multilevel analysis that can account for the lack of independence between observations.

Individual students were each observed for 30 consecutive minutes using an observation instrument to identify the nature of assignments, resources used, the frequency and nature of verbal interactions, and feedback received (see Appendix C). Observations were scheduled ahead with the teacher so that unusual situations such as testing days or field trips were avoided.

A battery-operated mini-desk recorder was used to record verbal interactions for later transcription and verification of the data collected in the classroom. The student placed the recorder on his or her workspace or in a pocket if he or she needed to move around frequently. The microphone was clipped to the student's collar. Stopwatches were used to time the overall observation as well as to note times of activity or assignment changes. The actual durations of each turn and interaction were not timed in the study due to the impracticality of timing numerous very short and rapid utterances that were typical of classroom conversations (in the pilot stage of the study, it was found that most turns lasted only a second). Instead, a measure of the length of interactions was provided by counting the number of turns per interaction.

Either one or two observers were present at each observation. The principal researcher was present at every observation, and one of two alternative observers was present at 90 of the observations in order to provide a measure of reliability to the data collected. The second observer recorded all information recorded by the primary observer except for verbal interactions, as these were captured on tape for later verification. After the observation, the observers compared records to ensure agreement on frequency and source of instructional feedback received by the observed student, coding of assignment type and length of time spent on different activities, groupings for activities, how the activities were assigned and uniformity across the classroom, resources used, and whether or not a resource was used at the observed student's initiative or in response to direction from the teacher.

Five of the students spoke only Spanish during the observation, and another 21 spoke both English and Spanish. In cases where the researcher was unable to accurately translate the Spanish for the purposes of categorizing verbal interactions, a fluent Spanish speaker familiar with both Dominican and Puerto Rican dialects was called upon to listen to the recordings after completing the observations in order to verify or provide translations.

Two of the 193 observations were discarded for data analysis purposes. In one case, 20 of the 30 minutes observed were spent on mathematics instruction rather than science, and in the other case, the mini-disk recorder malfunctioned so that none of the verbal data could be verified. The remaining 191 observations were analyzed.

All data collected from schools, teachers, and students through the various data instruments were entered into databases using SPSS and eventually subjected to statistical analysis using SPSS and HLM.

Development of the Data Instruments

The teacher questionnaire and the observation instrument were constructed using various pre-existing instruments as models. Some parts of the study instruments were borrowed directly from these pre-existing instruments as described below. The composition of the student questionnaire (see Appendix E) was influenced by a number of student surveys developed to evaluate Technology Innovation Challenge Grant projects, including the Eiffel Project based in New York City. These were available as part of the "TEI Instrument Exchange" facilitated by the United States Department of Education.

The teaching philosophy section of the Teacher Questionnaire (see Appendix B) was taken from a set of instruments developed by Ravitz and Light (2000) to predict constructivist-compatible pedagogy and technology use in classrooms. These instruments were publicly available for the purpose of selection and analysis of study sites provided that the authors were consulted regarding the researcher's purpose. Approval was received by e-mail dated 5/26/00 from J. Ravitz for use of this instrument in this study. This section was designed to assign teachers with a teaching philosophy score allowing them to be placed on a continuum from traditional (low scores) to constructivist or progressive teaching philosophy. This score was used in data analysis as a control variable for teaching philosophy.

The teacher technology skills section was made up of selected questions (q. 2-q. 5) from a questionnaire developed by V. Denes for the purposes of evaluating the Eiffel Project, a Technology Innovation Challenge Grant project. The questionnaire was available to researchers as part of the "TEI Instrument Exchange" facilitated by the United States Department of Education. This section was designed to allow extraction of a teacher technology skill score, also to be used as a control in data analysis.

The teaching practices section was made up of questions extracted from the same questionnaire developed by V. Denes (q. 11, 12) and from N. Maushak's questionnaire developed for the IOWA Star Schools project (q. 10). Both questionnaires were available as part of the "TEI Instrument Exchange" as explained above, and permission was received to use these specific questions from the actual authors. Additional items were inserted in the Maushak question to help address issues covered in the observation schedule developed for this study.

The teaching practices section was designed to support findings from the observations. While observation data were expected to be more reliable in terms of what actually happened in the classroom, they captured only a fraction of teaching time in the school year. The teacher's self-report data provided a longer-term perspective. Triangulating this information with the observation data and some questionnaire data from the students provided a means of validating the data collected. The teacher background information section utilized questions 19-23 of the aforementioned questionnaire developed by V. Denes. The question regarding student use of technology in the teacher's classroom was based on a question from the Virginia Technology Teacher's Survey (commissioned by the Virginia Department of Education, September 1998).

The Observation Schedule (see Appendix C) was a modified version of the Classroom Observation Schedule (COS) developed by Padron and Waxman (2000). Elements in the instrument were also adapted from Brophy and Good's (1970) dyadic interaction observation system, Marshall and Weinstein's (1986) Classroom Dimensions Observation System, and SRI International's Challenge Classroom Observation Instrument (obtained directly from SRI in 1999). H. Waxman reviewed the modified observation schedule and gave permission for adoption of his instrument model for use in this study.

Establishing the Reliability and Validity of the Observation Instrument

The observation measure in its modified form had not been used before, and therefore its validity as a measure of individualized instruction had not been tested. In order to assess the validity of the observation instrument and to develop reliability in its use, the primary researcher practiced using the instrument with around 15 students in a pilot study before actual commencement of the main study. Some of these practice observations were conducted with a second observer so that observations could be compared for agreement. The data collected were reviewed to ascertain whether meaningful conclusions could be drawn regarding the classroom environment. Appropriate changes were made to the instrument to allow for greater ease of use both in terms of collecting and interpreting the data. These pilot observations were not included in the actual study results. In the data analysis phase, results from the observation data and the questionnaire data were compared for agreement, as many items were duplicated across the instruments.

Timeline for Execution of the Study

9/00	Dissertation Committee approval of study proposal
	Proposal submitted to Teachers College Institutional Review Board (IRB)
	Proposal submitted to New York City Board of Education
	Potential schools sites identified
10/00	IRB and Board of Education approvals received

District superintendents/Principals contacted for permission to conduct study in particular schools

11/00	Teachers contacted to obtain consent regarding study participation Teacher questionnaires distributed
12/00	Teachers requested to select classrooms for study participation Consent forms and questionnaires distributed to students and parents/guardians
1/01	Observations begun
6/01	Observations completed
11/01	Mini-conference for teachers participating in the study to provide initial feedback on findings, to showcase use of computers in science instruction and to present science software
6/01-9/02	Data entry, tape transcription and statistical analysis.

Chapter IV

DATA ANALYSIS PROCEDURES AND SUMMARY OF RESULTS

The school level data collected using the School Data Sheets (Appendix A) provided background information regarding the sample of schools in the study. This dataset allowed an assessment of the generalizability of the study findings to other contexts and an investigation of how computer use and various indicators of individualized instruction might be associated with school factors. Strong associations would have indicated potential confounding factors in the investigation as to whether computer use was associated with the individualization of instruction. As previously noted, some of the school statistics were unreliable, as evidenced by discrepancies between principal reports and district reports for the same school.

While some correlational associations were found between school level factors and computer use (reported in Appendices G and H), in higher levels analyses it was generally found that these associations were less important than those between computer use and teacher, classroom, or student level variables.

The 50 teacher questionnaires were used initially to compile descriptive statistics summarizing issues relevant to teachers' technology use in the classroom. These topics, reported in detail in Appendix D, included teaching philosophy, teaching practices, attitude toward technology, technology skills, and teacher's use of computers in general and specifically with students in the science class. Much of this information was collected in order to allow various potential confounding factors to be controlled for in regression analyses. A number of scales were composed from the descriptive data for this specific purpose, including a teaching philosophy score, a score assessing the teacher's attitude toward computers, and a teacher technology skill score. Additionally, correlations between teacher reports of technology use in the classroom and student reports of technology use were checked to ascertain the reliability of the data collected.

The 673 student questionnaires were similarly analyzed with summary statistics regarding student technology use and skills reported in detail in Appendix F. A key independent variable, frequency of computer use in the science class, was reported in this dataset. A number of other self-reported variables from this dataset regarding student technology experience and use were employed as control variables in regression analyses, including scales reflecting students' technology skills and overall amount of technology use.

Additionally, the student questionnaires provided categorical, ordinal data on six indicators of individualized instruction in the science class: level of individual attention received by students for academic instruction; level of peer interactions for academic purposes; level of feedback received by students on their work; degree of choice in assignments worked on in class; level of variability in assignments across the classroom; and degree of choice in resources used to complete assignments. These six indicators were the outcomes subjected to further analysis in order to investigate the relationship between frequency of computer use and individualized instruction.

The 191 observations provided quantitative data regarding the frequency and nature of verbal interactions, the frequency and origin of feedback received by observed students, the nature of assignments worked on, and the types of resources used. These are reported in Appendix I. A second key independent variable, the amount of time a student spent using a computer during the 30-minute observation period, was reported in this dataset. Additional information was collected on classroom factors, such as the timing and location of the class, computer hardware availability, the number of Internet connections accessible, the number of students in the class, and the number of students using computers. These were investigated in statistical analyses for their potential mediating effect on the main relationship under investigation: the association between amount of time using a computer and individualized instruction.

While many observation outcomes are reported, 12 in particular, shown in Table 6, were selected as indicators of individualized instruction to be subjected to further analysis investigating their relationships with the amount of time spent using a computer. Parameters indicating the distribution of these outcomes are also summarized in Table 6. These were reviewed to help determine the best distributional approximation for analysis.

The major independent variables under investigation, frequency of computer use in the science classroom from the student questionnaires and time spent on the computer from the student observations, were correlated with student, teacher, classroom, and school variables in order to identify factors that were associated with computer use in the classroom. Significant associations were noted in order to help in the selection of control variables for inclusion in the regression analyses investigating the relationship between computer use and the various indicators of individualized instruction. These correlations are reported in Appendix G for the frequency of computer use and Appendix H for the amount of time spent on the computer. While these correlations

Table 6

Distribution of Observation Outcomes Selected as Indicators of Individualized Instruction

Outcome measure observed	Min	Max	Mean	SD	Skew	Kurtosis	Model for analysis
Number of verbal interactions	0	95	28.46	18.99	0.78	0.20	Poisson*
Number of turns per interaction	0	22	2.51	1.68	8.30	93.26	Poisson*
% of interactions that are on-on-one	*0.00*	*100.00*	*47.26*	*35.56*	*0.04*	*-1.44*	*Normal*
% of interactions that are one-on-one with teacher	*0.00*	*93.75*	*8.10*	*17.30*	*2.76*	*7.90*	*Normal but with square root taken*
% of interactions that are one-on-one with teacher and instructional	*0.00*	*0.94*	*0.06*	*0.15*	*3.33*	*12.40*	*Normal but with square root taken*
Number of feedback comments received	0	24	5.32	5.01	1.43	2.31	Poisson*
Number of activities	1	12	3.41	2.12	1.04	1.40	Poisson*
Minutes working independently	0	30	11.33	12.25	0.48	-1.49	Poisson*
Minutes working on assignments given by the teacher	0	30	27.73	5.69	-3.32	11.30	Poisson*
Minutes working on assignments the same as all students in class	0	30	15.88	13.20	-0.14	-1.81	Poisson*
Total number of resources used	2	10	5.02	1.53	0.74	0.35	Poisson*
% of resources used at student's own initiative	*0.00*	*100.00*	*16.51*	*20.42*	*1.23*	*1.18*	*Normal*

Note. Italicized items are percentages rather than original counts;

*Poisson models were all corrected for overdispersion in analysis, as the means and standard deviations were greater than 1.

allowed associations between variables to be identified, the lack of controls leaves some of these relationships questionable once other factors are considered.

Correlations Between Indicators of Individualized Instruction and Computer Use

As an initial investigation regarding the relationship between frequency of student computer use and the six indicators of individualized instruction reported on the student questionnaire, correlations were calculated as shown in Table 7. More frequent computer use was associated with students reporting more interaction with peers for academic purposes in science class compared with other classes, more feedback on their work in science class than in other classes; more choice in assignments, more variability in assignments across the class, and more choice in the resources used to complete assignments. There was no association between frequency of computer use and student-reported level of individual attention for academic instruction from the teacher in science class compared with other classes.

Using data from the two separate student datasets (questionnaire data and observation data), associations between actual observed computer use and the student-reported indicators of individualized instruction were also investigated (Table 7). More time using a computer was associated with students reporting more individual attention in science class compared with other classes, more feedback on their work in science class than in other classes, more choice in assignments, more variability in assignments across the class, and more choice in the resources used to complete assignments. There was no association between computer use and the student-reported level of interaction for academic purposes. At this level of analysis, the two different measures of computer use indicate similar relationships with four of the six indicators of individualized instruction.

Table 7

Correlations between Computer Use Measures and Indicators of Individualized Instruction

Indicator of Individualized Instruction	Reported Frequency of Computer Use	N	Observed Time Using Computer N = 191
Individual attention from teacher	.06	573	.22**
Peer interaction for academic purposes	.10*	569	.08
Amount of feedback received on work	.12**	593	.17*
Amount of choice in assignments	.19**	672	.24**
Variability in assignments across the class	.27**	673	.31**
Amount of choice in resources	.21**	673	.17*

Regression Analysis of Computer Use and Indicators of Individualized Instruction

A number of regression analyses followed to investigate the relationships between computer use in the science class and the selected indicators of individualized instruction with a number of potential confounding factors included as controls. The questionnaire data and observation data were analyzed separately and the results compared.

Summary of Regression Results for Frequency of Computer Use and the Six Indicators of Individualized Instruction Reported in the Student Questionnaires

For the questionnaire data, three sets of regression analyses were conducted on each of the six indicators of individualized instruction. Appendix J describes multilevel analysis in general and the specific regression models used for this analysis in detail. Appendix K reports the actual results of the analyses. The first set of regression analyses, random intercept only models, determined whether each outcome variable under investigation (e.g., amount of peer interaction) varied significantly across classrooms. For each of the six indicators tested, this was found to be the case, indicating a need for multilevel regression analysis to allow these differences across classrooms to be explained while at the same time recognizing that the data are nested so that students in the same classroom cannot be considered totally independent.

A second set of regression analyses, fixed effect models, investigated the relationships between frequency of computer use and each indicator, controlling for the student's grade point average (GPA) but assuming that the indicator does not vary across classrooms. While the first regression analysis showed in each case that this assumption would be incorrect, this is the typical assumption of traditional single level regression analysis, so that these results are presented alongside the third regression analysis to show how multilevel analysis can alter the conclusions drawn from the data.

The third and final set of regression analyses investigated the relationships between the frequency of computer use and each indicator of individualized instruction assuming that the outcomes vary across classrooms but also controlling for the student's GPA and a second-level set of teacher and classroom variables. These included the teacher's teaching philosophy score, the teacher's attitude toward computers, class size, the number of working computers available, the frequency of project work in the classroom, the teacher's ethnicity, the teacher's gender, and the type of class (regular/ accelerated/bilingual/other).

While many other variables could be candidates for inclusion as controls in the regression analyses, limitations of sample size required that only the most salient variables be included in the final models. Variables such as the student's gender, age, and grade level were investigated in trial analyses but found to have no significant impact on the models in most cases. Consequently, these were omitted in favor of other variables that had greater explanatory power. Where it was found that an additional variable did have a significant impact on a particular outcome, it was included for that outcome only.

Table 8 summarizes, for each outcome, which predictor variables were significantly related to the outcome. The intra-class correlation (ICC) is a measure of the variability in the outcome that is due to the teacher/classroom level and therefore can be used as one indicator of whether a two-level analysis is preferable to a traditional single level analysis. For all six outcomes, the ICC is above 0.05, the usual threshold level above which a multilevel analysis is merited. Another measure of whether there is enough difference in the outcomes between classrooms to merit multilevel analysis, the final estimation of variance components (reported in Appendix K), confirms in each case that there is significant variability across classrooms. It can be concluded that in all six cases, the multilevel analysis should be taken as the most reliable analysis. The between-group variance (BGV) explained by the teacher/classroom level variables (teacher's gender, ethnicity, etc.) reflects how well the variables selected for inclusion in the model explain the differences found among classrooms. The values for BGV indicated in Table 8 suggest that the teacher/classroom variables included in these regression models were fairly effective in accounting for the differences in outcomes apparent among classrooms.

Reviewing the results of the various analyses for each outcome provides a clear view of how conclusions vary depending on the sophistication of the analytical

Table 8

Significant Predictors of Indicators of Individualized Instruction from Student Questionnaire Data

Outcome	ICC	Fixed model		Multilevel model		BGV %
		Predictor	Effect	Predictor	Effect	
Individual attention	0.12	GPA	-0.02	GPA Computer Use Latino Teacher	-0.02 +0.35 +1.36	40
Peer interactions	0.13	Computer use	+0.24	Grade level Female Teacher	-0.44 -0.62	54
Feedback received	0.17	Computer use	+0.28	GPA Female teacher Asian/Other teacher Textbook use	-0.02 +0.67 +1.17 -0.34	52
Choice in assignments	0.14	GPA Computer use	-0.03 +0.50	GPA Computer use	-0.03 +0.29	31
Variability of work	0.25	Computer use	+0.65	Computer use Bilingual class	+0.51 +1.44	53
Choice in resources	0.15	GPA Computer use	+0.03 +0.41	GPA Computer use White teacher	+0.04 +0.31 -1.06	51

Note. ICC = Intra-class correlation; BGV = between-group variance explained by teacher/classroom level variables included in the regression model.

method employed. The initial Pearson's bivariate correlation between the frequency of computer use and the student-reported amount of individual attention received from the teacher for academic purposes indicated no significant relationship (Table 7, p. 81). A single level regression controlling only for student's GPA rendered the same conclusion (Table K1, p. 246), although it appeared that students with lower GPAs received more individual attention. However, once a number of teacher and classroom variables (teacher's philosophy, teacher's attitude towards computers, frequency of project work, teacher's gender and ethnicity, class size and type, number of computers available in the classroom) were controlled for in a multilevel model, it became apparent that more frequent computer use was indeed associated with students reporting more individual attention (Table K1). Students with lower GPAs also received more individual attention, as did students of Latino teachers.

The initial Pearson's bivariate correlation between the frequency of computer use and the amount of student interactions with peers for academic purposes indicated a positive relationship (Table 7, p. 81). A single level regression controlling for student's GPA confirmed this relationship with no significant effect for GPA (Table K2, p. 248). However, with the inclusion of the student's grade level and the teacher and classroom variables noted above as additional controls in a multilevel model, the relationship no longer appeared significant (Table K2). The amount of interaction did appear greater among students of lower grades and among students of male teachers.

The initial Pearson's bivariate correlation between the frequency of computer use and the amount of feedback received by students on their work indicated a positive relationship (Table 7, p. 81). The single level regression controlling only for student's GPA supported this conclusion (Table K3, p. 250). However, once a number of teacher and classroom variables were included as additional controls in a multilevel model, the relationship was no longer significant (Table K3). These second-level controls included those listed above for the individual attention outcome plus the frequency of textbook use in the classroom. A number of variables were found to predict feedback levels: greater textbook use resulted in less feedback received by students, students of female teachers received more feedback, students with lower GPAs received more feedback, and students of teachers in the "Other" ethnicity category (primarily Caribbean-American and Asian-American teachers) received more feedback.

Greater frequency of computer use was, according to the Pearson's bivariate correlation, associated with students reporting more choice in the assignments worked on in class (Table 7, p. 81). The single level regression controlling only for student's GPA supported this conclusion as well as indicating that students with lower GPAs had more choice in assignments (Table K4, p. 252). The multilevel model with additional controls for the teacher's philosophy score, teacher's attitude toward computers, frequency of project work, teacher's gender and ethnicity, the number of working computers available in the classroom, and class size and type supported the conclusion that students who use computers more frequently have more choice in the assignments they work on in class (Table K4). The association between lower GPA and more choice in assignments was also supported.

The Pearson's bivariate correlation indicated that more frequent use of computers was associated with students reporting less uniformity in the work assigned to students across the classroom (Table 7, p. 81). This was supported by the single level regression controlling only for student's GPA and by the multilevel model with additional teacher and classroom variables included as controls (Table K5, p. 254). Students in bilingual classes also reported less uniformity in the work assigned across students in the classroom.

The Pearson's bivariate correlation indicated that more frequent use of computers was associated with students reporting more choice in the resources used to complete their assignments (Table 7, p. 81). The single level regression controlling only for student's GPA supported this conclusion and also indicated that students with higher GPAs reported more resource choice (Table K6, p. 256). The multilevel model, with teacher and classroom variables included as controls, supported both these findings as well as indicating that students of White teachers reported less choice in resources than students of teachers in other ethnic groups (Table K6).

Based on these analyses, it can be concluded that more frequent computer use is positively associated with four of the six indicators of individualized instruction, even when a number of other factors are controlled for: amount of individual attention received, amount of choice in assignments, amount of variability in assignments across the class, and amount of choice in resources used. No association was found, in the final analysis, between frequency of computer use and amount of peer interaction or amount of feedback received. Twelve of the outcome measures from the observation data (listed in Table 6, p. 79) were selected to provide further support and clarification of these conclusions.

Summary of Regression Results for Computer Use Time and the Twelve Indicators of Individualized Instruction from the Observation Data

From the observation data, 12 different outcomes were investigated and the three regression models run for each as was done for the questionnaire data: a random intercept only model, a fixed effects model, and a final two-level random intercept model. The analyses and models are explained in Appendix L, and detailed results are reported in Appendix M. The key predictor variable in each case was the number of minutes the student was observed using a computer. In the second two models, a number of student variables were included as controls: student's age, student's gender, student's GPA, and number of minutes spent working on a project. Unlike the regression models for the questionnaire-based indicators, these models included student age and gender as controls, given the significant impact they had on a number of the models. Frequency of project work, a teacher-reported variable in the questionnaire dataset, was replaced by the actual time the observed student engaged in project work in the observation analyses.

Second-level variables included as controls in the final two-level model were the teacher's gender and ethnicity and whether or not the class was regular as opposed to bilingual, honors, accelerated, or other. The other second-level variables that were included in the questionnaire data models (the teacher's philosophy score, the teacher's attitude toward computers, class size, and the number of working computers available) were omitted because tests indicated that dropping them had no significant impact on the model outcomes and the need for model parsimony was even greater given the smaller size of this dataset (191 observations as opposed to 673 questionnaires). Table 9 summarizes the significant predictors for each outcome.

For 2 of the 12 indicators of individualized instruction measured in the observation dataset, frequency of feedback and minutes working on assignments given by the teacher, low ICCs (Table 9) and low variances (indicated in Table 9 but shown in detail in Appendix M) indicated that traditional single level, fixed effects models were adequate for analysis. Given the small number of observations per classroom (just under 4 on average), this finding is not surprising. Even where a multilevel analysis was merited, the teacher/classroom variables included at the second level varied in their effectiveness at explaining the differences in outcomes across classrooms with BGV values (shown in Table 9) ranging from 0 to 99%. In cases where the second-level variables are ineffective in explaining the differences in outcomes across classrooms, it

Table 9

Significant Predictors of the Indicators of Individualized Instruction from the Observation Data

Outcome	ICC	Var	Fixed model		Multilevel model		BGV %
			Predictor	Effect	Predictor	Effect	
Number of verbal interactions	0.01	√	Time on computer	-0.01	Time on computer	-0.01	20
			GPA	+0.01	Time on projects	+0.01	
			Female student	+0.11			
			Student age	-0.06			
			Time on projects	+0.01			
Number of turns per interaction	0.09	√	Time on projects	+0.01	Time on computer	+0.01	48
					GPA	-0.01	
					Time on projects	+0.01	
					White teacher	+0.18	
% of interactions that are one-on-one	0.35	√	Time on computer	+0.62	Time on computer	+0.74	5
% of interactions that are one-on-one with teacher (SQRT)	0.18	√	Time on computer	+0.06	Time on computer	+0.06	†
					Time on projects	-0.04	
% of interactions that are one-on-one with teacher and instructional (SQRT)	0.23	√	Time on computer	+0.01	Time on computer	+0.01	13
					Time on projects	-0.00	
Number of feedback comments received	0.01	x ‡	GPA	+0.01	Female student	+0.32	†
			Female student	+0.28			
Number of activities	0.12	√	Time on computer	-0.02	Time on computer	-0.02	78
			Time on projects	-0.01	Time on projects	-0.01	
					Female teacher	+0.25	

table continues

Table 9 (continued)

Outcome	ICC	Var	Fixed model		Multilevel model		BGV %
			Predictor	Effect	Predictor	Effect	
Minutes working independently	0.12	√	Time on computer GPA Student's age	+0.04 -0.03 -0.10	Time on computer Time on projects	+0.04 -0.02	17
Minutes working on assignments given by the teacher	0.00	x ‡	None		None		0
Minutes working on assignments the same as all students in class	0.13	√	Time on computer Time on projects Student's age	-0.04 -0.05 -0.07	Time on computer Time on projects	-0.04 -0.05	100
Total number of resources used	0.11	√	Time on computer	+0.01	Time on computer	+0.01	23
Percentage of resources used at student's own initiative	0.47	√	Time on computer	+0.82	Time on computer	+0.77	49

Notes to Table 9. ICC = Intra-class correlation; BGV = between-group variance explained by teacher/classroom level variables included in the regression model; Var = whether there is significant variance between classrooms (from the random intercept only model).

† For this outcome the final model variance is actually larger than the variance for the random intercept only model indicating that there are better teacher/classroom predictors for this outcome.

‡ Given the small variability in the outcome among classrooms the single level, fixed effects model is adequate for regression analysis.

must be concluded that other factors should be included in the model. Identifying these factors would be a valuable endeavor for a future study or for further analysis of this dataset. In general, the results from the observation dataset are more tenuous because of the smaller sample size.

For the verbal interaction outcome, a significant level of variance among classrooms indicated that a multilevel analysis was merited despite a low ICC value (Table 9). The final regression model (Table M1, p. 271) indicated that more time on the computer was associated with fewer verbal interactions when other factors were controlled for. This was counter to expectations. The analysis also indicated that more time spent on projects led to more verbal interactions, no doubt because project work was often undertaken in groups leading to a great deal of peer interaction. Associations identified by the fixed effects model between verbal interactions and GPA, female student gender and student age (Table M1, p. 271) disappeared in the multilevel model.

Although the actual number of interactions were fewer for students using computers the most, the number of turns per interaction was higher (Table M2, p. 274), suggesting that while these students interacted less, the interactions were of greater duration. Other factors in the multilevel model that predicted more turns per interaction were more time on project work, a lower GPA, and having a White teacher.

More time spent on the computer also predicted, above and beyond the other factors controlled for in the final models, a higher percentage of turns that were one-on-one (Table M3, p. 276), a higher percentage of turns that were one-on-one with the teacher (Table M4, p. 277), and a higher percentage of turns that were one-on-one with the teacher and also instructional (Table M5, p. 279). However, it is apparent from

Table 6 (p. 79) that one-on-one turns with the teacher for instructional purposes constituted, on average, a very small percentage of turns overall. The latter two outcomes, the percentage of turns that were one-on-one with the teacher and the percentage of turns that were one-on-one with the teacher and also instructional, were negatively associated with time spent on projects. Presumably students interacted less one-on-one with the teacher while working on projects because they were generally working in small groups. They may also have relied more on each other instead of addressing the teacher.

Overall it is apparent that computer use was associated with a number of changes with respect to verbal interactions in the classroom. Increasing computer use was associated with fewer total interactions, but the interactions that did occur were more protracted. Additionally, students using computers engaged in more one-on-one interactions with other individuals in the classroom and specifically with the teacher for instructional purposes. This latter finding is certainly significant given the fears of many critics that computer use might lead to less student interaction with the teacher.

Also counter to expectations, computer use did not predict observed levels of feedback received by students on their work (Table M6, p. 281). Feedback levels observed were, in general, low and varied little across classrooms so that a single level analysis sufficed in modeling the data. The fixed effects regression model did indicate that female students received more feedback than male students and that students with higher GPAs received more feedback than those with lower GPAs.

Greater computer use and more time on project work predicted fewer changes in activity during the 30-minute observation period (Table M12, p. 291). During the observations, it was often apparent that students using computers for Internet research or for creating projects persisted longer on a single activity, whereas students working without computers were more often directed to switch activity by the teacher. The final regression model also indicated that students of female teachers switched activity more often than those of male teachers.

Students spending more time using computers and those spending more time on project work were also more likely to be working independently than those not using computers (Table M8, p. 284) and more likely to be working on assignments that differed across students in the classroom (Table M7, p. 283). Assignments were, however, almost always given by the teacher rather than chosen or designed by the students whether or not they were using computers, so that none of the variables in the regression model predicted differences in this outcome (Table M9, p. 286). From the descriptive statistics in Appendix I, it is clear that variability in assignments arose due to students choosing different topics or executing a given assignment in different ways or at different paces (Table I12, p. 229).

Students using computers used a wider range of resources to complete their assignments (Table M10, p. 288). While it is self-evident that these students would be using a computer and some software, students using computers did not ignore other resources such as peers, the teacher, books, or teacher-provided material. Furthermore, students using computers more were more likely to demonstrate initiative in using a resource rather than waiting to be directed to resources by the teacher (Table M11, p. 289).

Based on these analyses, it can be concluded that time spent using a computer was significantly associated with all but two of the twelve indicators of individualized instruction from the observation data. In one case, the overall number of verbal interactions, the association was the opposite of expectations, with more computer use being associated with fewer interactions overall. In the two cases where no association was found, the number of feedback comments received and the amount of time spent working on assignments given by the teacher, the outcomes were found to be quite homogeneous across classrooms, so that it was not surprising that computer use did not predict whatever small differences existed. These findings regarding the outcomes selected as indicators of individualized instruction from the observation data are compared with those from the questionnaire data to provide a fuller picture of how computer use appeared to be associated with individualized instruction.

Comparison of the Results for the Indicators of Individualized Instruction from the Student Observation Data with the Student Questionnaire Data

The questionnaire data posed a direct question to students regarding the level of individual attention received from the teacher for academic purposes. A multilevel analysis controlling for a number of student, teacher, and classroom variables indicated that students who used computers more frequently were more likely to claim greater individual attention from the teacher (Table K1, p. 246). This result was substantiated by the finding from the observation data that students using computers more in the science class were observed engaging in more one-on-one interactions with the teacher for instructional purposes than students using computers less (Table M5, p. 279).

Additionally, students who were observed using a computer more were also more likely to work independently than students using a computer less (Table M8,

p. 284). While independent work in itself does not necessarily lead to more individual attention from the teacher, it becomes easier for the teacher to attend to a single student if he or she is not working as part of a group or the whole class.

While multilevel analysis of the questionnaire data showed that, controlling for a number of student, teacher, and classroom variables, frequency of computer use does not predict the overall level of peer interactions for academic purposes in science class (Table K2, p. 248), the observation data painted a much more complex picture. The multilevel analysis of observed student verbal interactions indicated that students who spent more time using a computer in class actually interacted less overall than students using a computer less (Table M1, p. 271). However, these interactions tended to be more protracted, with more student turns per interaction (Table M2, p. 274). Furthermore, more of these interactions were exchanged with a single counterparty as opposed to multiple counterparties (Table M3, p. 276), and these students interacted more one-on-one with the teacher than students not using computers (Table M4, p. 277).

Both sets of data indicated that, once a number of student, teacher, and classroom variables were controlled for, there was no relationship between computer use and the amount of feedback received by students (Tables K3, p. 250, and M6, p. 281). However, it appears that female students received more feedback than male students, that female teachers provided more feedback than male teachers, that teachers of Asian or other ethnic categories provided more feedback than White, Latino, or African-American teachers, and that greater textbook use in the classroom resulted in less feedback to students. Contradictory results regarding the effect of student's GPA on feedback levels arose in the two different datasets.

The student questionnaire data indicated that students who used computers more frequently in the science class had more choice in the assignments they worked on (Table K4, p. 252) and experienced less uniformity in the assignments given to students across the class (Table K5, p. 254). The observation data presented a clearer picture of what students were experiencing as "choice." It appears that, irrespective of computer use, the teacher generally directed what assignment was to be worked on rather than letting students make this decision (Table M9, p. 286). However, observations confirmed that students who used computers more did experience greater variability in assignments (Table M7, p. 283). They were given more flexibility to complete the assignment according to personal interests, execution preferences, and pace of working.

The questionnaire data indicated that students who used computers more frequently had more choice in the resources they used to complete their assignments than students who used computers less (Table K6, p. 256). This finding was supported by the observation data that showed that students using computers more also used a greater number of resources than students using computers less (Table M10, p. 288) These students also used their own initiative more often in selecting resources to use (Table M11, p. 289).

The next chapter begins by comparing these results with the initial set of ten hypotheses predicting the kinds of changes expected in the classroom when computers were used.

Chapter V

CONCLUSIONS, DISCUSSION, AND POLICY RECOMMENDATIONS

Conclusions

Overall, the preceding results appear to support the overarching hypothesis that computer use facilitates the individualization of instruction in classrooms. Returning to the initial set of ten hypotheses, it appears that the findings unequivocally support five of the hypotheses regarding changes expected in the classroom environment when students use computers. These five hypotheses address the amount of individual attention received by students from the teacher, the uniformity of assignments, the nature of assignments, and resource use. Four other hypotheses are supported with modifications. These relate to the frequency and nature of verbal interactions, student grouping in the classroom, and the amount of choice in assignments. Only one hypothesis, regarding amount of feedback, appears incorrect.

The first hypothesis suggested that students using computers receive more individual attention from the teacher than students not using computers. It was found that students who used computers more frequently also reported receiving more individual attention from the teacher for academic purposes in the science class than students using computers less frequently. Furthermore, it was observed that students who spent more time using a computer during class engaged in more one-on-one conversations with the teacher for instructional purposes.

The second hypothesis postulated that students using computers would engage in more frequent verbal interactions in the classroom than students not using computers and that these interactions would be of greater duration. The observation data actually indicated that total verbal interactions were less frequent as computer use increased but that those verbal interactions were indeed more protracted. The correlation data did indicate a relationship between more computer use and more time on task as well as fewer personal/social verbal exchanges, so that one possible conclusion is that while students interacted less, this was because they spent less time chatting with peers for social reasons and more time focused on their work. This conclusion should be investigated further in a future study.

The third hypothesis stated that individual or small group interactions as opposed to large group interactions would be more frequent for computer-using students than for non-computer-using students. The observations indicated that the percentage of overall interactions that were one-on-one among peers and between students and the teacher was greater as computer use increased. No significant difference was found with respect to small group interactions. This is, no doubt, related to the fact that, in this study, students using computers were just as likely as students not using computers to be working in small groups but more likely to be working independently. More small group work would most likely have resulted in more frequent small group interactions. More time spent on the computer was also associated with fewer whole group interactions.

The fourth hypothesis speculated that feedback on academic efforts would be more frequent and varied in terms of origin when students were using computers than when they were not. Surprisingly, given the increase in one-on-one interactions among peers and between students and the teacher, neither the student-reported data nor the observations supported this hypothesis. The amount of feedback received by students on their work was similar whether or not students used computers. The only hint of difference arose in the correlation analysis of the data, where it appears that more computer use was associated with fewer feedback comments directed at the whole class. Perhaps one explanation for this lack of difference is that the incidence of feedback was fairly low in all circumstances, especially in the case of written feedback. This finding in itself raises an issue for educators and policymakers to review in terms of whether students are getting enough direct commentary on the quality of their work, whether from the teacher, peers, or other parties. The lack of written feedback being provided to students should be of particular concern.

The fifth hypothesis suggested that tasks assigned to students across the class are less uniform when computers are used more. This was indeed found to be the case based both on the students' own reports and actual observations. Interestingly, no incidences were observed where the teacher assigned tasks differentially based on students' academic abilities or learning styles. However, variations arose when students were allowed to express their own interests in choosing a specific topic in order to complete a given assignment, for example, the subject of a project or a research paper. Additionally, students using computers were more often seen working at different paces. For example, a student who had completed a laboratory assignment on micro-organisms might move on to research a particular micro-organism on the Internet while other students finished making observations with a microscope. In other instances, when students were working in groups, the students would divide tasks among themselves so that, for example, one student might conduct some research on the Internet, another look for textbook material, another word-process a report, and another collect materials for a poster-board.

The sixth hypothesis postulates that students using computers more have greater choice in assignments worked on in class than students using computers less. Student reports did support this hypothesis, but observations clarified exactly what constituted the "choice" experienced by the students. It was clear from the observations that teachers generally dictated the type of assignment to be completed, whether or not computers were being used. However, students using computers were more often able to choose the specific topic, decide how to complete the assignment, work at their own pace, and choose from a greater variety of resources.

The seventh hypothesis proposes that students using computers work independently or in small groups as opposed to working as a whole class more often than students not using computers. The observation data indicated that students using computers were indeed likely to spend more time working independently, although no difference was found in the time spent working in small groups.

The eighth hypothesis suggests that students using computers are more likely to work on open-ended assignments, such as projects. This was supported in a number of different ways. Greater student computer use was strongly associated with teachers who reported more frequent assignment of project work. During the classroom observations, the actual type and length of activity engaged in by the student was noted. Students using computers were most often working on a project, conducting research on the Internet, or word processing. Conversely, greater computer use was associated with less time listening to or watching the teacher, working on problems and exercises, participating in teacher-led discussions or question-and-answer sessions, and conducting laboratory sessions or experiments. While word processing is generally not open-ended in nature, project work and research on the Internet are usually more open-ended than the types of activity that were associated less with computer use. An additional supporting finding was that students using computers switched activity less often during class than students not using computers, often spending the entire class on a single task.

The ninth and tenth hypotheses propose that students using computers use a greater variety of resources than students not using computers and that the resources are more often used spontaneously rather than in response to teacher direction. Students who reported more frequent computer use also reported greater choice in resources. During the observations, actual resources used were counted and were indeed more numerous for students using computers. Additionally, students using computers were more often observed selecting a resource at their own initiative.

While a number of other factors were significantly associated with the indicators of individualized attention, in most cases the extent of computer use had a predictive value above and beyond these other variables. The other significant variables included the amount of time spent on project work, the frequency of textbook use, the student's gender, the student's grade level, the student's GPA, the teacher's ethnicity, the teacher's gender, and the type of class. It is somewhat surprising that the teacher's teaching philosophy, while strongly correlated both with a number of the indicators and actual computer use, faded in importance once other variables were included in the models. It is probable that the teacher's gender and ethnicity variables are strong predictors of teaching philosophy so that they obscure the philosophy effect when all three variables are included in the regression model at once. Additionally, contrary to expectations, class size did not have a significant impact on the outcomes once other variables had been included in the model.

Contribution to the Field of Knowledge Regarding the Impact of Computer Use on Classroom Environment

This study has taken a number of hypotheses found in the existing literature regarding the impact of computer use on the classroom environment and tested them in a field study that was as rigorous in design as is practical in typical public school situations. The study did not set out to contrive an "ideal" comparison between students using computers and those not using computers; instead, it compared real-life situations in a variety of settings. The findings can therefore be assumed, to a reasonable degree, to reflect the impact of computer use in urban, public middle school science classrooms. The findings may also apply to other settings. Clearly, the degree of generalization must be tempered by the fact that all schools in the study were located in Manhattan. It was, however, clear from the statistical analyses of the data that school level variables were not as important in affecting the outcomes under investigation as teacher and classroom factors and student level variables.

Most previous studies regarding the impact of computers in the classroom have relied on self-report data by teachers or, in some cases, students. A few have relied on observations by trained researchers. This study has combined all three different types of data source to increase the reliability of the findings. Student and teacher questionnaire data provided a relatively large sample of self-report data depicting the classroom environment over an extended period of time. Student observations provided a smaller sample of first-hand and highly detailed data over a short, fixed period of time.

The study purposefully accounted for a host of potential confounding factors that have limited the ability of many previous studies to conclude that changes found in the classroom can be predicted by the use of computers. These include use of projects as a means of instruction, access to hardware and software, the teachers' teaching philosophy and own expertise with computers, students' achievement levels, and demographics. Information regarding potential confounding factors was collected about the schools participating in the study, the teachers whose students participated, the classrooms in which the relevant students attended science classes, and the students themselves through a combination of self-report and observation data. While this study concluded that a number of other factors were indeed important in predicting the indicators of individualized instruction under investigation, by accounting for them, conclusions were drawn about the predictive value of computer use above and beyond these confounding factors.

Finally, by analyzing the data with multilevel statistics, a technique that has only recently been employed in evaluating educational data, the usual problems associated with nesting effects in studies of students grouped within classrooms were minimized. This allowed for increased confidence in the significance of the findings and also permitted differences in student level outcomes to be accurately attributed, where relevant, to teacher or classroom factors.

Significance of Findings

Having ascertained that computer use is associated with a number of changes in the manner in which students interact and work with each other and the teacher in the classroom, the question arises as to whether these changes are desirable and beneficial. While clearly a fully substantiated response to this question would require several follow-up studies, some preliminary assessment can be made by examining whether the identified changes might support the development of skills deemed desirable. In the introductory chapter to this dissertation, desirable skills mentioned by researchers included the capacity for "sustained and substantial inquiry and analysis" (Honey et al., 1999, p. 3). Additionally, McNabb et al. (1999) refer to the ability to think creatively or critically, to the development of collaborative teamwork skills, lifelong learning abilities, and computer literacy. More generally, a classroom environment that is more student-centered than teacher-centered and that promotes constructivist rather than traditional learning is currently considered more desirable, as evidenced by the reference in the PCAST report (1997) to constructivist applications of computers as potentially one of the most promising uses of computers in schools.

It would seem that the capacity for sustained and substantial inquiry and analysis might be increased by giving students opportunities to interact at length on instructional issues, by allowing an extended focus on a single assignment as opposed to the regular switching of activity, and also by presenting the option to select and access a wide range of resources, including the extensive research possibilities of the Internet and Worldwide Web. Thinking creatively or critically might be facilitated by allowing students the opportunity to pursue a range of interests rather than having the teacher mandate all parameters of assignments to be worked on. This freedom to pursue individual interests and the creation of situations where students use their own initiative to select learning resources are arguably important factors in developing lifelong learning abilities. Allowing students to interact with one another or the teacher on a more personalized level and completion of group project work, often associated with computer use, might be expected to engender teamwork skills.

While, in fact, it would seem that many of these desirable skills are addressed by engaging students in project work, it can be concluded from the statistical analyses in this study that computer use predicted the outcomes under investigation above and beyond the effects of project work. In practice, assigning project work with computers to be used as a tool for execution is likely to maximize the opportunities for students to develop these skills.

The development of computer literacy should be facilitated by the opportunity to use computers frequently for a range of purposes, including those that can be carried outside the classroom and beyond school years, such as Internet research. By reviewing the purposes for which computers were being used in the science classroom and the kind of software that was being employed, it was clear in this study that students were using the computer more often as a tool for executing their work rather than simply as a substitute for other resources, such as the teacher, peers, reference books, or textbooks. The capacity to use a computer both as a means and an end suggests a positive step toward genuine computer literacy rather than simply computer facility.

In terms of addressing the aim toward establishing a more student-centered and constructivist classroom environment, the study findings provide much to support the use of computers in facilitating the process. Students using computers were found to have more scope to follow their own interests, more opportunity to use their own initiative in selecting their tools, and a wider variety of resources to aid completion of their work. These students also had more opportunity to work independently and to interact in individualized settings rather than functioning as part of a whole group working lockstep on uniform, teacher-directed assignments.

Stepping back from the focus on higher level skills, the question should also arise as to how the observed outcomes might affect the acquisition of more basic skills and knowledge in the classroom as well as the level of student motivation. It would seem self-evident that when students have more opportunity to interact with the teacher or peers on an individual level, their own particular questions would be more often addressed. This study found that computer-using students more often called on the teacher or peers for help than students not using computers and asked or answered more questions addressing procedures and requesting clarification of issues.

Close assessments would be necessary to judge the actual impact of computer use on basic skills such as reading and writing. It was, however, noted in the study that students using computers read aloud more frequently than students not using computers. Often this involved a voluntary reading of text from a website to share relevant or interesting information with peers. One of the common uses of computers was for word processing, and, while only anecdotal, teachers often referred to the increase in quantity of output from students when using computers. However, increased quantity of written work may or may not translate into increased quality.

Access to a greater range of resources may make a wider knowledge base available to students, although whether or not this is utilized effectively would need to be documented in another study. Allowing students to tailor their work according to their own interests, work at their own pace, and choose their own resources would be expected to help increase student motivation.

Beyond hypothesizing about how the outcomes observed in this study might translate into desirable skills, the study findings can also be used to address some other issues in the literature. Critics of computers have often questioned the impact of computer use on socialization and have sometimes predicted a deterioration of the teacher-student relationship. It is apparent from this study that, while computer use is associated with changes in the nature of interactions, the trend is toward slightly fewer, more personalized and complex interactions with both teacher and peers rather than whole group interactions. For example, students using computers interacted more often one-on-one with the teacher for instructional purposes than students not using computers.

Limitations of Findings and Suggestions for Further Work

Clearly, this study focused on some very specific aspects of the learning environment that provide only a small part of the overall picture representing how knowledge and skills are gained in the classroom. The study investigated process rather than outcome, with the aim of explaining some of the mechanisms by which computer use might affect outcomes. Referring back to Honey et al. (1999), the goal has been to understand how innovation occurs in schools, not simply to document the outcomes correlated with the treatment. There was no attempt to measure any kind of achievement outcome that might be affected by computer use, for example, to rate the quality of the work produced by the students, to measure the quantity of work achieved in a set period of time, or to measure achievement scores that might be affected by computer use. Achievement scores were collected for control purposes only, but no attempt was made to measure how much knowledge was gained or how much certain skills improved. These are all highly relevant issues in determining whether or not computers add value in the classroom and merit studies of their own. The findings of this study can be used to help explain how computer use might be influencing the outcomes investigated.

It should also be noted that, while the relationship between computer use and the designated indicators of individualized instruction, such as individual attention, verbal interactions, feedback, level of choice and uniformity in assignments, and choice in resources, were subjected to rigorous statistical analysis using control variables, other findings reported from this study are based on correlation data with no controls. As such, these findings should be subjected to further analysis to ascertain their validity or, better still, new studies designed to specifically address those issues. Ideally, the findings of this study could be used to inform the design of fully randomized or at least well-matched experiments to investigate the impact of computer use on student achievement outcomes. Slavin (2002) argues that nothing short of these rigorous forms of research will suffice in order to give policymakers confidence to act upon the findings.

Future studies might further improve upon the design of this study by increasing the sample sizes to allow for more reliable statistical tests and additional levels in the multilevel analysis. In this study, only two levels were considered, a teacher/classroom level and a student level. A school level could be added if more schools were included in the study, with at least five classrooms selected from each school. Additionally, or alternatively, a grade level or student's age level could be introduced by sampling sufficient classrooms and students from each of various grade levels or age groups. In this study, grade level and age were not treated as separate levels due to sample size limits, although these variables were used as controls to check for the impact on the relationships being investigated and were found not to be significant predictors of most of the outcomes.

A better view of individualized attention specifically could be gained by observing the teacher in the classroom and examining periods of attention afforded to individual students across the class. Differences in the frequency and length of these periods could be compared in computer-rich versus computer-poor classrooms. By noting whether the student receiving the individualized attention was using a computer or not, differences in the teacher's behavior towards computer-using students as compared with non-computer-using students could be identified.

One of the themes regarding changes in the learning process associated with computer use that arose in the literature but was not fully investigated in this study was the notion that students using computers take more responsibility for their work. Some of the outcomes in this study support this idea, for example, students spending more time using a computer took the initiative to select resources for use more frequently than students spending less time on a computer. However, a fuller investigation is merited. Developing a range of valid indicators of this concept would be required before undertaking any study to measure them.

Another aspect of school computer use that is of importance to policymakers but not addressed by this study is the question of cost-effectiveness. While the outcomes observed in this study might be considered positive, whatever gains are made must be balanced by the costs of computer hardware, software, maintenance, and professional development. Arguably, studies like this one that aim to determine whether and how computer use, above and beyond other factors, is associated with classroom outcomes are prerequisites to meaningful assessments of whether any resulting gains are cost-effective. However, in the interests of fiscal responsibility, such cost-effectiveness studies should eventually follow.

Policy Recommendations

Based on the conclusion that computer use is associated with a number of apparently desirable changes in the classroom environment, policy actions should focus on engendering the use of technology in the classroom. Support for such actions should be forthcoming from the main stakeholders in education. Taxpayers, ever seeking some positive outcome of educational interventions in public schools to justify the vast government expenditures on education, should be satisfied that beyond bringing schools into technological step with the working world, computer use is associated with changes in the classroom environment that appear to enhance the quality of students' learning experiences. Teacher unions should voice little objection to a tool that, rather than replacing the teacher as a resource in the classroom as once feared, improves the teacher's ability to attend to individual learning needs. Parents are likely to be pleased that their children are receiving more individualized instruction. Funding and assistance from corporations should be easy to procure, particularly where developers and manufacturers of hardware and software are concerned. Policymakers who fail to heed the positive potential of technology will rapidly run the risk of losing support to rivals who develop effective strategies for harnessing this potential.

This study identified many factors associated with greater technology use, some of which can be addressed by policy actions. For example, schools involved in multiple technology initiatives experienced the most impact in terms of teacher and classroom use of computers. Policymakers need, however, to reassess the kinds of initiatives that should be funded and improve the coordination of these efforts. The fragmented nature of educational policymaking caused by multiple layers of governance at the state and local district levels, with additional influence by the federal government, has resulted in a plethora of technology programs, both public and private. Technology-related resources and directives have been targeted at different players in the education field, with little overall strategic direction for technology infusion into schools. Any single initiative inevitably becomes diluted first in filtering through layers of bureaucracy and second in operating alongside other initiatives that may or may not be complementary. Each state would benefit from the creation of a high-level, long-term appointment to coordinate efforts toward technology integration in schools. Currently, the most effective initiatives appear to be those organized by small not-for-profit entities focusing directly on classroom teachers and students rather than the larger scale efforts sponsored by government agencies that often address peripheral players who are not directly affecting classroom outcomes.

Two such large-scale efforts that have come under recent scrutiny to determine effectiveness are the federally sponsored Technology Innovation Challenge Grant (TICG) Program (funded 1995-2000) and the Technology Literacy Challenge Fund (TLCF, funded 1997-2001 and now replaced by the Enhancing Education through Technology or Ed-Tech program, see http://www.ed.gov/offices/OESE/SST/edtech.html). Adelman et al. (2002) compared various technology-related outcomes in schools benefiting from the

TLCF with those not benefiting from such grants. They did not find any association between TLCF grant participation and teacher-reported frequency of student computer use. This dissertation study investigated the association between involvement in the TICG Program and computer use. Participation in this initiative appeared to be associated with more frequent computer use in the science classroom, although not necessarily with greater length of time using the computers.

The TLCF and TICG programs are examples of a class of policy instruments that McDonnell and Elmore (1987) term "inducements." These particular inducements aim to leverage a limited amount of public funding by inviting public-private partnerships to propose innovative uses of technology. The advantage of this type of policy instrument over a mandate, for example, is that participants, having had to compete actively for limited funds by proposing strategies for using technology effectively in schools, are more likely to make an effort to effect the policy goals. The disadvantage is that only a small percentage of students are able to benefit and only do so based on the enthusiasm of the educators around them to apply for and utilize the requisite resources. Furthermore, the relatively short-lived nature of these programs fails to provide the continuity of effort that is necessary to assure that new ideas take hold long-term in actual classroom practice. In Slavin's (2002) terms, they are a reflection of the tendency for educational practice to ride "the pendulum of educational fashion" (p. 19).

More wide-reaching policy instruments, such as capacity-building programs, while likely to be more effective, would clearly require greater amounts of funding. Such programs need to be selectively targeted at the key players in control of the desired outcomes and closely tracked to assure implementation. Relevant areas for policy considerations with respect to engendering technology use in classrooms include teacher training programs, ongoing professional development efforts, technology support in schools, hardware and software access, and enforcement of standards for student technology capabilities.

According to Skinner (2002) in a recent *Education Week* review of national technology trends, only 26 states and the District of Columbia currently require technology training or coursework for initial teacher licensure, and only 7 require demonstration of technology competence. Additionally, a mere four states require technology training for teacher recertification. While 13 states offer professional or financial incentives for teachers to use technology, such as free laptops or continuing education credits, the total of all these efforts falls far short of ensuring that all teachers are equipped to take advantage of the technology currently in place in schools. State-level policymakers across all states should include technology capabilities in teacher licensure and recertification requirements.

At the federal level, a small effort to address teacher training in technology has been made through the Preparing Tomorrow's Teachers to Use Technology (PT3) grant program (see http://www.ed.gov/teachtech/), but the latest appropriation of only $62.5 million for 2002 will assure that the program will only allow for a few potential showcase models to be developed. Clearly, the burden of responsibility in terms of teacher preparation falls to state policymakers, even if they choose to look to the federal PT3 program for valuable ideas to adopt or adapt.

In order to emphasize the need to address student technological capabilities, states should follow up requirements for teacher preparation with requirements for student preparation. While 36 states and the District of Columbia currently publish standards specifically addressing technology skills, only 3 states have developed tests to assess whether these standards are being met (Skinner, 2002).

Dexter, Ronnkvist, and Anderson (2000) demonstrate the importance of technology support for teachers learning to incorporate technology into their activities. This dissertation study supports their argument in that schools with a dedicated technology professional showed greater use of computers by students in the classrooms. Adelman et al.'s (2002) survey indicated that teachers found school-level technology coordinators to be the most useful source of technology support. Ensuring that all schools have at least one professional dedicated full-time to supporting and training teachers in technological issues would be a valuable policy aim.

It is clear from this dissertation study that the teacher's attitude toward computers and his or her length of experience and skill in using them have an impact on student computer use in the classroom. Interestingly, classroom observations and conversations with the teachers indicated that teachers are generally comfortable having students use the computers, regardless of their own expertise, provided the teacher can find a useful purpose and organize the class effectively to use the resources available. In particular, many teachers questioned how to manage a class effectively with only 4 computers available to 30 students. These insights imply that professional development activities in technology skills and teacher education programs should address issues such as connecting instructional uses of technology to curriculum objectives, identifying the appropriate technology for a curricular unit and classroom management strategies rather than simply building the teacher's own execution skills on the computer. Similar conclusions can be drawn from national studies such as Adelman et al.'s (2002)

2000-2001 survey of public school teachers conducted as part of the United States Department of Education's Integrated Studies of Educational Technology (ISET). The ISET data indicated that half of the teachers reported no support or inadequate support for learning to integrate computer activities into instruction.

In order to sufficiently fund professional development activities, all states should follow the example set by the federal government in the No Child Left Behind Act of 2001, which mandates that 25% of technology funds be spent on professional development. This would be a substantial improvement from the current average of 15% of technology funds reported by schools as being spent on staff development (Market Data Retrieval, 2002). Furthermore, beyond improving the quality of professional development activities, states should develop a range of incentives to encourage teacher participation. Adelman et al. (2002) note that providing release time from classes, recertification credits, and additional resources for the classroom appear to be more effective in encouraging teachers to participate in technology-related professional development than other policy mechanisms.

The earlier discussion regarding the skills that computer use might help students develop concluded that assigning project work to students with computers available as a tool for execution is likely to maximize the opportunities for students to build skills in substantial inquiry and analysis, to think creatively and critically, and to develop teamwork and communication skills. Teaching teachers how to effectively guide students in executing project work with computers would appear to be a useful focus both in professional development activities and in pre-service training programs.

Professional development activities vary greatly in their nature and usefulness, so that developing effective methods of training teachers to incorporate technology skills into the classroom is of great importance. While this dissertation study did not formally assess which kinds of initiatives specifically translated into more computer use, those that participating teachers claimed to be most effective involved a technology expert, whether another faculty member or an outsider, working one-on-one with the science teacher on an ongoing basis in the classroom. A study by Desimone, Porter, Garet, Yoon, and Birman (2002) indicates that, in the specific case of technology-related professional development, there is a benefit to the collective participation of teachers from the same school, department, or grade level because teachers are subsequently able rely on one another in developing and implementing technological skills.

Building on these ideas, a possible strategy for effective professional development might pursue the following trajectory. Within a particular geographical area, for example, a school district, a small number of teachers could be identified as competent and effective users of technology in the classroom. This could be done by sending observers to schools in the district or by asking principals and technology coordinators to recommend teachers. A series of workshops could be arranged in which these effective users of technology could showcase actual student activities and describe classroom management procedures to a wider audience of teachers in the district. These effective users could be provided a financial reward for the time spent preparing for the workshop beyond official recognition as an effective technology user.

To maximize the relevance of the workshops to the audience, it would make sense to have, for example, middle school science teachers present to an audience of other middle school science teachers. This would ensure that the type of activities showcased were age appropriate and directly relevant to the curricula being taught. Many studies (e.g., Adelman et al., 2002; National Center for Education Statistics (NCES), 2000) have indicated that time is one of the biggest constraints on teachers incorporating technology into the classroom. The time available for developing lesson plans is generally limited enough without adding the extra requirement of finding ways to incorporate technology. However, demonstrating activities that require little or no modification before being used directly in the classroom would increase the likelihood of adoption. Of course, those teachers who wished to make modifications should be free to do so. Additionally, any software that was used in a demonstration should be available for the teacher to take away for immediate use. A number of educational software providers have developed free demonstration software specifically for the purposes of distribution to teachers during such training efforts.

Following up from the workshops, teachers could then be invited to sign up to work one-on-one with one of the effective technology users of their choice. This teacher-trainer could, over a period of time such as a semester or full school year, help other teachers incorporate technology as a tool in the execution of the curricula being followed in their classrooms and attend some class sessions to assist in the classroom management function. Providing one or both teachers in each partnership with some incentive, financial or otherwise, for the continuation of this team effort could improve the chances of success of this strategy.

Keller (2000) describes a strategy executed along these lines in New York's Oswego School District. Two teachers were initially trained in instructional technology by experienced hardware and software vendors. These teachers trained other teachers in the district, and these, in turn, became trainers for their schools. As a result, the average Oswego teacher received 160 hours of in-service training in instructional technology. Following the completion of data collection in this dissertation study, all the participating teachers were invited to attend a mini-conference at which several teachers showcased student activities using computers in their classrooms and a variety of science software was set-up for teachers to explore at their leisure on desktop or laptop computers. Attendance was purely voluntary, and yet around 50% of the teachers participated in the event and many indicated they would like to have the opportunity to follow up with specific teachers.

While appropriate teacher training is clearly a priority for educational technology efforts in schools, the availability of working hardware, software, and Internet connectivity is obviously a prerequisite to computer use in the classroom. Studies, including this one, repeatedly confirm the strong association between computer availability and use so that policymakers can be assured that continuing to fund hardware and software availability as well as Internet connectivity is worthwhile. However, policymakers should heed the findings of various studies (Adelman et al., 2002; Becker et al., 1999; NCES, 2000) that computer use is more strongly associated with availability in actual classrooms as opposed to computer laboratories. Furthermore, efforts should be made toward streamlining the process of acquiring hardware and software and responding to teacher needs rather than making top-down decisions as to what should be available. The teachers in this study often complained of arduous paperwork trails involved in procuring specific software or hardware and years of waiting for Internet connections, while equipment that had not even been requested lay idle elsewhere in the school.

Teachers participating in this study also complained about the poor quality of content-specific software. Given the fragmented nature of the school market for software purchasing, it is not surprising that software developers have lacked the motivation to develop quality content for the classroom. An attempt to work with content developers to create a viable public school market for high quality educational software would help assure a product that is both profitable for the vendors and valuable to the users. Clearly, involving practicing teachers and students directly in software development would improve the relevance of content to its potential users.

While the above recommendations presuppose the value of computers and other technology in the classroom, the need for continuous research on effective applications of technology and evaluations of interventions cannot be ignored. Slavin (2002) describes and lauds the recent shift by users of educational research to demand randomized experiments for evaluations of educational interventions and policies. However, he also describes the difficulties and enormous expense associated with recruiting schools into true experiments or rigorously matched experiments. Policymakers must attend to the issue, not only of funding such high quality research, but also facilitating access to research participants. In the design section of this dissertation study, a detailed description was provided of the many layers of bureaucracy that had to be negotiated in order to gain access to a study sample. Such barriers to obtaining random samples must be lowered to allow for studies that provide information about the effectiveness of interventions in the typical classroom, rather than in a rarified subset pre-screened by administrators. As such research becomes available, the establishment of an independent review commission, of the type suggested by Slavin, specifically focusing on research concerning technology in K-12 classrooms would provide a clearinghouse for findings on which policymakers could rely.

In summary, while continuing to provide access to software, hardware, and Internet connectivity is a prerequisite for effective computer use in schools, this alone is not enough. Content must be more directly useful to the end-users. Training teachers effectively in the use of technology must extend beyond engendering basic skills to address actual incorporation with teaching strategies. Providing support on demand for the teachers and the actual technology on an ongoing basis is critical to make the initial investment yield a potentially worthwhile return. Localized and targeted initiatives that aim directly at classroom teachers and students, especially those providing individualized and ongoing on-site support for teachers, are more likely to yield immediate, tangible results than grand schemes addressing large numbers of peripheral players.

Appendix A

SCHOOL DATA SHEET

Name of School ______________________________ Number of School ____________

Address ____ District # _____________

____

____

____

Principal
Mr./Ms./Dr. ______________ Tel: ______________ Fax: _______________

Total number of teachers ___________

STUDENTS
Total number of students enrolled _________

% female ____________ % male ____________

% receiving reduced price or free lunch ____________
% English Language Learners ____________
% Special education ____________

% in each ethnic group				
	African-American	______	Asian-American	______
	Latino	______	Native American	______
	White	______	Multiracial	______
	Other	______		

Number of students in grade 6_____ 7_____ 8_____

TEST SCORES: % meeting state standard on:

Grade 8 English Language Arts Tests ______ (yr:.........)

Grade 8 Mathematics test ______ (yr:.........)

PARTICIPATION IN TECHNOLOGY INITIATIVES

Project CONNECT
Project SMART
Eiffel/ Gateways
Other initiatives?
Who could I ask for more information about this?
Name Position Tel/e-mail

Appendix B

TEACHER CONSENT LETTERS AND QUESTIONNAIRE

TEACHER INVITATION LETTER

Human Development, 453 GDH
Teachers College, Columbia University
525 West 120th Street
New York, NY 10027

7 October 2000

Dear Teacher

I am a doctoral candidate at Teachers College, Columbia University and am planning to observe a number of students in New York City classrooms to investigate how the presence or absence of technology, such as personal computers, affects teaching and learning in science classes. While the study focuses on students, I will need to determine certain characteristics of the teacher that might affect classroom activity.

In order to make sure that differences seen between students are not simply a result of different teaching styles, I would like you to respond to a questionnaire regarding your philosophy of teaching and experience with classroom technology. It will take about 15-20 minutes to check off the questionnaire items. Later I will ask you to distribute consent forms and questionnaires to the students in your classroom. For those who agree to participate, I will need grades and any relevant test scores.

Student questionnaires include questions regarding their technology use and skills. Later, two or three students will be observed individually during the regular course of a lesson. Observations will focus on the nature of verbal interactions, how resources are used and the type of assignments being worked on. An audiotape will be used, with permission, so that verbal interactions can be analyzed for length, content and frequency. Any such tapes will be destroyed once the research is complete. The observation should not interfere with the students' activities during class time.

All information will remain anonymous and confidential. Participation in this study is entirely voluntary and participants may withdraw at any time, with no consequences. Please feel free to call me on 212 362 9227 with any questions or concerns. Additionally, if you have any concerns regarding this study you may contact the Institutional Review Board at Teachers College, Columbia University, 212 678 4105 or 525 W 120th Street, New York NY 10027, Box 151.

Please return this letter to me indicating whether or not you agree participate in this study.

Thanking you in advance

Yours sincerely

Fiona Hollands

I ________________________________ agree/do not agree to participate in the above study

Signed: ______________________ Date: ________

Investigator's signature : _________________ Date: ________

Teachers College, Columbia University
Institutional Review Board for the Protection of Human Subjects

Informed Consent Part II:
PARTICIPANT'S RIGHTS

Principal Investigator: Fiona Hollands

Research Title: A comparison of high and low technology classrooms with respect to the individualization of students' learning experiences.

I have read and discussed the Research Description with the researcher. I have had the opportunity to ask questions about the purposes and procedures regarding this study.

My participation in the research is voluntary. I may refuse to participate or withdraw from participation at any time without jeopardy to future medical care, employment, student status or other entitlements.

The researcher may withdraw me from the research at his/her professional discretion.

If, during the course of the study, significant new information that has been developed becomes available which may relate to my willingness to continue to participate, the investigator will provide this information to me.

Any information derived from the research project that personally identifies me will not be voluntarily released or disclosed without my separate consent, except as specifically required by law.

If at any time I have any questions regarding the research or my participation, I can contact the investigator, who will answer my questions. The investigator's phone number is (212) 362 9227.

If at any time I have comments, or concerns regarding the conduct of the research or questions about my rights as a research subject, I should contact the Teachers College, Columbia University Institutional Review Board/IRB. The phone number for the IRB is (212) 678 4105. Or, I can write to the IRB at Teachers College, Columbia University, 525 W. 120th Street, New York NY 10027, Box 151.

I should receive a copy of the Research Description and this Participant's Rights document.

If audiotaping is part of this research,
I ( ) consent to be audiotaped.
I ( ) do NOT consent to being audiotaped.
The written and audiotaped materials will be viewed only by the principal investigator and members of the research team.

Written and/or audiotaped materials
( ) may be viewed in an educational setting outside the research
( ) may NOT be viewed in an educational setting outside the research

My signature means that I agree to participate in this study.

Participant's signature: ______________________ **Date:** / /

Name: ______________________

If necessary:
Guardian's signature/consent: ______________________ Date: / /

Name: ______________________

TEACHER QUESTIONNAIRE

Teacher code #

Thank you for agreeing to help me in this study of the effect of technology on teaching and learning. While the study aims to focus primarily on students, the teacher's style will obviously have a great impact on what is observed in the classroom. To help sort out the effects of technology from teacher effects, this questionnaire is designed to get an idea of how you teach.

Please check or circle answers to the following questions. There are four sections covering A) your teaching philosophy, B) your technology skills, C) your teaching practices and D) your background.

Please return the completed questionnaire to me in the enclosed envelope.

This header sheet with your name will be detached from your responses upon receipt and you will be assigned a code in order to keep your answers completely confidential.

Name: ______________________

TEACHER QUESTIONNAIRE
Teacher code #

PART A) YOUR TEACHING PHILOSOPHY

A1. The following paragraphs describe observations of two teachers' classes, Ms. Hill's and Mr. Jones'. Check the boxes that best answers that question for you.

Ms. Hill was leading her class in an animated way, asking questions that the students could answer quickly; based on the reading they had done the day before. After this review, Ms. Hill taught the class new material, again using simple questions to keep students attentive and listening.

Mr. Jones' class was also having a discussion, but many of the questions came from the students themselves. Though Mr. Jones could clarify students' questions and suggest where the students could find relevant information, he couldn't really answer most of the questions himself.

a. Which type of class discussion are you more comfortable having in class? *(check one)*

Definitely Ms. Hill's ☐
Tend towards Ms. Hill's ☐
Can't decide ☐
Tend towards Mr. Jones' ☐
Definitely Mr. Jones' ☐

b. From which type of class discussion do you think students gain more knowledge? *(check one)*

Definitely Ms. Hill's ☐
Tend towards Ms. Hill's ☐
Can't decide ☐
Tend towards Mr. Jones' ☐
Definitely Mr. Jones' ☐

TEACHER QUESTIONNAIRE
Teacher code #

A2. Indicate how much you agree or disagree with each of the following statements about teaching and learning.

	Strongly disagree	Moderately disagree	Slightly disagree	Slightly agree	Moderately agree	Strongly agree
a. Students will take more initiative to learn when they feel free to move around the room during class	☐	☐	☐	☐	☐	☐
b. A quiet classroom is generally needed for effective learning	☐	☐	☐	☐	☐	☐
c. It is better when the teacher, not the students, decides what activities are to be done	☐	☐	☐	☐	☐	☐
d. Students should help establish criteria on which their work will be assessed	☐	☐	☐	☐	☐	☐
e. Instruction should be built around problems with clear, correct answers, and around ideas that most students can grasp quickly	☐	☐	☐	☐	☐	☐
f. It is very important for students to share their work outside their classroom	☐	☐	☐	☐	☐	☐

TEACHER QUESTIONNAIRE
Teacher code #

A3. Different teachers have described very different teaching philosophies to researchers. For each of the following pairs of statements, check the box that best shows how closely your own beliefs are to each of the statements in a given pair. The closer your beliefs to a particular statement, the closer the box you check. Please check only one for each set.

a. "I mainly see my role as a facilitator. I try to provide opportunities and resources for my students to discover or construct concepts for themselves."	☐ ☐ ☐ ☐ ☐	"That's all nice but students really won't learn the subject unless you go over the material in a structured way. It's my job to explain, to show students how to do the work, and to assign specific practice."
b. "It is a good idea to have all sorts of activities going on in the classroom. Some students might produce a scene from a play they read. Others might create a miniature version of the set. It's hard to get the logistics right, but the successes are so much more important than the failures."	☐ ☐ ☐ ☐ ☐	"It's more practical to give the whole class the same assignment, one that has clear directions, and one that can be done in short intervals that match students' attention spans and the daily class schedule."

TEACHER QUESTIONNAIRE
Teacher code #

A4. Indicate how much you disagree or agree with each of the following statements:

	Strongly disagree	Moderately disagree	Slightly disagree	Slightly agree	Moderately agree	Strongly agree
a. I know of many exciting and effective ways to use computers and network resources to teach	☐	☐	☐	☐	☐	☐
b. Computers and networks in school are, to a large extent, distractions that take time and energy from more important concerns.	☐	☐	☐	☐	☐	☐
c. The use of computers in the school's core curriculum is not appropriate for many students	☐	☐	☐	☐	☐	☐
d. Computers create more classroom problems than they solve	☐	☐	☐	☐	☐	☐
e. I don't think computers add a lot to the curriculum (other than knowledge about computers)	☐	☐	☐	☐	☐	☐
f. Computers may be useful for teaching and learning some things, but personally I don't see how they could be helpful in the classes I teach.	☐	☐	☐	☐	☐	☐
g. I have learned how to teach in new ways as a result of technology	☐	☐	☐	☐	☐	☐
h. I am excited about using computers more in my work as a teacher	☐	☐	☐	☐	☐	☐

TEACHER QUESTIONNAIRE
Teacher code #

PART B) YOUR TECHNOLOGY EXPERIENCE

B1. Do you currently have a computer in your home that you use regularly?

YES ☐ NO ☐

If you have a computer at home, please answer the following:

a) Does your home computer have a CD/ROM drive?

YES ☐ NO ☐

b) Does your home computer have Internet access?

YES ☐ NO ☐

B2. Please indicate approximately how many hours during an average week you use computer technology for the following tasks (both at home and at school).

a) word processing ____________________

b) record-keeping/administrative use ____________________

c) e-mail ____________________

d) research or information gathering on the Internet ____________________

e) part of classroom instruction ____________________

f) other (please specify) ____________________ ____________________

B3. Approximately how many hours of technology-related professional development have you received during this school year?

____

TEACHER QUESTIONNAIRE

Teacher code #

B4. Please indicate your skill in the following areas:

	None	Low	Adequate	Good	Excellent
a) word processing	☐	☐	☐	☐	☐
b) database/spreadsheets	☐	☐	☐	☐	☐
c) desktop publishing	☐	☐	☐	☐	☐
d) charts/graphing	☐	☐	☐	☐	☐
e) presentation software	☐	☐	☐	☐	☐
f) subject matter specific software/ CD/ROMs	☐	☐	☐	☐	☐
g) research on the Internet	☐	☐	☐	☐	☐
h) communication by e-mail	☐	☐	☐	☐	☐
i) video-conferencing	☐	☐	☐	☐	☐
j) technical maintenance/troubleshooting	☐	☐	☐	☐	☐
k) connecting instructional uses of technology to curriculum objectives	☐	☐	☐	☐	☐
l) digital portfolio development	☐	☐	☐	☐	☐
m) authoring/hypermedia development	☐	☐	☐	☐	☐
n) audio/video capture or digitizing	☐	☐	☐	☐	☐
o) Web page development	☐	☐	☐	☐	☐
p) determining how to organize students during technologically-enhanced instruction	☐	☐	☐	☐	☐
q) determining how time should be allocated during technologically-enhanced instruction	☐	☐	☐	☐	☐
r) identifying the appropriate technology for a curricular unit	☐	☐	☐	☐	☐

TEACHER QUESTIONNAIRE

Teacher code #

PART C) TEACHING PRACTICES

C 1) This question asks you about your use of certain teaching approaches and activities. In your 6th - 8th grade science classes, approximately, how often do you:

	Never	Occasionally but less than monthly	1-4 times per month	5-10 times per month	Every class
a. use small group based cooperative or collaborative learning activities	☐	☐	☐	☐	☐
b. have students work independently	☐	☐	☐	☐	☐
c. have students work on projects	☐	☐	☐	☐	☐
d. have students work on worksheets	☐	☐	☐	☐	☐
e. have students work from textbooks	☐	☐	☐	☐	☐
f. assign students to tutor others	☐	☐	☐	☐	☐
g. have students listen to teacher presentations	☐	☐	☐	☐	☐
h. group students by ability	☐	☐	☐	☐	☐
i. assign different activities to students based on their academic abilities	☐	☐	☐	☐	☐
j. have students do oral presentations	☐	☐	☐	☐	☐
k. have students review/discuss peers' work	☐	☐	☐	☐	☐
l. give students a choice in activity based on interest	☐	☐	☐	☐	☐
m. allow students a choice among resources to complete their work	☐	☐	☐	☐	☐
n. have students develop their own learning activities/projects	☐	☐	☐	☐	☐
o. give individual verbal feedback to a student on work	☐	☐	☐	☐	☐
p. give individual written feedback to student on work	☐	☐	☐	☐	☐
q. have students synthesize information from a variety of sources	☐	☐	☐	☐	☐
r. organize learning activities to specifically improve students' standardized test scores?	☐	☐	☐	☐	☐

TEACHER QUESTIONNAIRE
Teacher code #

C2) This question asks you about your use of computer technology in classroom instruction. Which of the following statements best describes your use of technology in your 6th - 8th grade science instruction? *(Check only one).*

☐ I have not used computer technology at all in my instructional program and do not intend to use it this school year.

☐ I have not used computer technology at all in my instructional program, but I am thinking about trying to use some this year.

☐ I use computer technology once in a while in my class.

☐ I have integrated computer technology into specific instructional units.

☐ Computer technology is fully integrated in my instructional program.

C3) For how many years have you been using computer technology in your classroom?

....

C4) Please describe any differences computers or other technology have made to your teaching:

....

....

....

....

C5) Please describe briefly the curriculum you follow in your 6th, 7th or 8th grade science classes. Are there any standards you have to meet or tests your students are required to take?

....

....

....

TEACHER QUESTIONNAIRE
Teacher code #

C6) How much time per week, does a typical student in your 6th, 7th or 8th grade science class spend on the following activities using technology?

	None	Less than 15 mins	15-30 mins	30-60 mins	More than 60 mins
a) view videotapes or television in a non-interactive environment	☐	☐	☐	☐	☐
b) view videodisks in an interactive environment (e.g. Jasper Woodbury series)	☐	☐	☐	☐	☐
c) participate in an interactive video environment	☐	☐	☐	☐	☐
d) use graphing/scientific calculators	☐	☐	☐	☐	☐
e) use computers for any educational purpose	☐	☐	☐	☐	☐
f) use word processing software	☐	☐	☐	☐	☐
g) create/manage/analyze databases	☐	☐	☐	☐	☐
h) create/manage/analyze spreadsheets	☐	☐	☐	☐	☐
i) create/share presentations using presentation software	☐	☐	☐	☐	☐
j) conduct research using CD/ROMs	☐	☐	☐	☐	☐
k) conduct research using the Internet	☐	☐	☐	☐	☐
l) create/maintain Web pages	☐	☐	☐	☐	☐
m) use desktop publishing or graphics software	☐	☐	☐	☐	☐
n) use e-mail to communicate with peers for educational purposes	☐	☐	☐	☐	☐
o) use e-mail to communicate with experts for educational purposes	☐	☐	☐	☐	☐
p) use content-related programs for drill and practice	☐	☐	☐	☐	☐
q) other (please specify)____________	☐	☐	☐	☐	☐

TEACHER QUESTIONNAIRE
Teacher code #

PART D) YOUR BACKGROUND

D1) Are you MALE FEMALE

D2) Is your ethnicity African-American Asian-American

Latino Native American

White Multiracial

Other (please specify)_______________

D3) What is the highest degree you have received?

Bachelor's	Master's +30 credits	Doctorate
Master's	Master's +45 credits	Other (Please specify)________

D4) Which grades do you teach? *(Circle all that apply)*

7 8 9 10 11 12

D5. Please LIST the subjects you teach:

_____________ _____________ ___________________

D6. How many years have you been teaching?_____________

D7. How many years have you been teaching in this school?______________

D8. How old are you? _____________

THANK YOU FOR YOUR TIME

Appendix C

Observation Instrument and Instructions for Use

OBSERVATION INSTRUMENT Header sheet

Date	Time
Observer	School
Location	

STUDENT

Student being observed (code only)	Male/female
Age	Ethnicity
Grade level	Average grade for this class
Standardized test score	Student technology expertise score

TEACHER

Teacher (code only)	Male/female
Number of years teaching	Teacher philosophy score:
Teacher technological expertise score:	

CLASSROOM

Subject	Class designation if any (e.g. honors)
Number of students in class	# of multimedia computers
# of Internet connections	Length of lesson
Other equipment available (list type and quantity)	

Describe the goals and objectives of the lesson being observed to provide a context for the observation data. Note curriculum in use and and standards to be met/tests required.

OBSERVATION

Observation #:																		
VERBAL INTERACTIONS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Parties involved in turn (O/S/L/W)																		
with teacher																		
with peer(s)																		
with administrator																		
with other																		
Duration of turn *(seconds)*																		
Nature of turn *(check one)*																		
student question																		
part of student-facilitated discussion																		
student presentation																		
response to teacher's question/comment																		
part of teacher-facilitated discussion																		
response to peer's question/comment																		
reading aloud																		
other (specify)																		
Content of turn																		
instructional																		
disciplinary																		
administrative																		
personal/social																		
Type of question if instructional *(check one)*																		
yes/no or agree/disagree																		
factual recall: single correct answer																		
factual recall: multiple possible answers																		
opinion																		
reasoning																		
problem-solving: single correct answer																		
problem-solving: multiple answers possible																		

OBSERVATION

Observation #:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
FEEDBACK	*Check incidence of instructional feedback received by student, written (W) or verbal (V) and +,- or 0*																	
from peer																		
from teacher																		
from other (specify)																		
directed at individual																		
directed at pair																		
directed at small group (3-7)																		
directed at large group (8+)																		
TYPE OF ASSIGNMENT *record time (seconds) spent on each type of activity*																		
listening to/watching the teacher																		
copying notes																		
working on problems/exercises																		
reading assigned material																		
viewing video/slides																		
teacher-led discussion/Q/A session																		
devising problems/tasks																		
open discussion																		
conducting experiments as per instructions																		
experimenting freely																		
peer tutoring																		
presenting																		
working on a project																		
free reading																		
free writing																		
computer simulations/software																		
researching in the library/internet																		
other (specify) e.g. off-task (OT)																		
GROUPING *check whether the above assignment was worked on:*																		
independently																		
in pair																		
in small group (3-7)																		
in large group (8+)																		

OBSERVATION

Observation #:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
UNIFORMITY OF TASKS	*For each assignment the student engages in note whether the assignment is:*																	
same for all students																		
varies in academic difficulty																		
varies according to student interests																		
varies according to learning styles																		
varies in other way (specify)																		
given by teacher																		
selected by student from list of alternatives																		
devised by observed student																		
devised by other student																		
USE OF RESOURCES	*Check each incidence of student engagement with the following resources for instructional purposes only. Note if teacher has directed activity (T) or student has taken the initiative (S)*																	
teacher (listening to /watching teacher etc.)																		
teacher-provided material on board/overhead																		
peers																		
textbooks																		
worksheets																		
primary source documents																		
reference books																		
library books/papers																		
on-line material																		
computer software																		
TV/video																		
outside experts																		
other (specify)																		
NOTES (student generally on/off task, discipline issues etc.)																		

Observation Instrument: Instructions for Use

1. Prior to commencing the observation, fill out as much of the header sheet as possible using information from the student and teacher questionnaires where necessary. The observed student should be instructed to act as if the observer is not present during the 30-minute observation period. Any questions that arise during the 30 minutes should be addressed at the end.

2. The instrument should be used for 30 consecutive minutes once a lesson has begun to check off the appropriate boxes describing: each of the observed student's verbal comments; each incident in which the student receives feedback, written or verbal; each assignment the student works on; each type of resource used.

3. The box at the end should be used for any notes regarding issues not specifically measured by the instrument but which may help explain the data. For example, issues of discipline, degree to which student is on task and so forth.

Directions and Operational Definitions

Verbal Interactions

Turn: a series of words or phrases spoken by one individual without interruption from another person. Each box on the grid represents a single turn of the observed student. When a turn consists of several parts, for example, one part responding to a question and another posing a question, code the last part only. The following types of turn are not counted as meaningful turns: any comment directed at the observer; repetitions of the same word/s to the same person unless requested by the counterparty; any comments out loud by student to him/herself; singing unless obviously intended for a peer to receive an overt message from it; reading aloud to self.

Interaction: A series of turns exchanged by the observed student and one particular person or group of people. An interaction ends when the counterparty changes. In situations where the conversation continues with the same counterparty/ies, the interaction ends when there is a pause of more than a few seconds in the interchange, sometimes, but not always, accompanied by a change in topic. Sometimes a topic changes without any pause and this is considered a continuation of the first interaction. The end of an interaction is signified by a thick pencil line drawn on the right hand side of the box representing the observed student's last turn in that interaction.

Parties involved. Each time the observed student speaks to another person during class time note whether the comment ("turn") is primarily aimed at the teacher, a peer or peers, an administrator or someone else. For each turn indicate whether the context is:

- one-on-one (O); as part of a small group of 2-7 people (S); as part of a large group of 8 or more people (L); as part of the whole class (W).

Duration of turn. Record length of student's comment in seconds using a stopwatch.

Nature of turn. Categorize each turn as one of the following types:

- *Student question*: observed student initiates an isolated question (not as part of an extended discussion). If the observed student responds to a question with a question the turn could be coded as Response to Peer's/Teacher's Question or as Student Question. Use Student Question unless it appears that the new question is intended only to answer the initial one rather than widen the topic under discussion.

- *Part of student-facilitated discussion*: in such a discussion, while the teacher may contribute comments, he or she is not leading by directing who should speak or which issues should be addressed. It may be a discussion only among students.
- *Student presentation*: observed student is presenting prepared comments to part or all of the class with or without visual aids.
- *Response to teacher's question/comment*: observed student answers a teacher's question (mark a "Q") or responds to a comment by the teacher (mark a "C").
- *Part of teacher-facilitated discussion*: observed student contributes to a discussion primarily directed by the teacher who indicates who should speak, what issues to address and so forth.
- *Response to peer's question/comment*: observed student answers a peer's question (mark a "Q") or responds to a peer's comment, not as part of an extended discussion (mark a "C").
- *Reading aloud*: observed student reads aloud from a text, paper, board, screen or other written material.
- *Other (specify):* observed student's verbal comments do not fall into any of the above categories. For example, mark "C/A" for calling attention.

Type of question. If the observed student either poses or responds to a question, record the complexity of the response required by checking one of the following categories:

- *Yes/no* or *agree/disagree*: one word answer either affirming or negating the questioner's remark.
- *Factual recall: single correct answer*: only one possible answer is correct (e.g. "What is the symbol for the element sodium?").
- *Factual recall: multiple possible answers*: several possible responses could be correct (e.g. "Give me some examples of herbivorous animals.").
- *Opinion*: the question requires the respondent to use judgment or personal preference (e.g. "What do you think is the most unusual feature of dinosaurs?").
- *Reasoning*: the question requires some form of logical reasoning or hypothesizing using factual knowledge as well as judgment (e.g. "Why might cutting down rain forests have a detrimental effect on the environment?").
- *Problem-solving: single correct answer*: respondent is required to verbally work through a problem requiring several steps and to which there is only one correct answer (e.g. "If a cell divides every half an hour then after two hours how many cells would there be?").
- *Problem-solving: multiple correct answers possible*: respondent is required to verbally work through a problem which has several possible correct answers (e.g. "If a carnivore needs to consume 3000 calories per day, give me a combination of prey that could satisfy this requirement.").

Other types of question can be noted in the last space or below.

Content of Turn. Check whether the content of the turn is primarily:

- *Instructional*: comments are related to learning purposes such as explaining or asking about facts or concepts, how to solve problems, use equipment or conduct experiments, checking work, checking for understanding.
- *Disciplinary*: comments either in response to discipline statements or initiated by the student him/herself (e.g. "I was not talking to Susan", "Quit making that noise Devon, I can't concentrate.").
- *Administrative*: such comments are not primarily instructional but may be related to classroom routines, directions for work, requests to leave the room, move around or move onto another task. (e.g. "What page are we on?", "Why can't I work on my project today?", "What was for homework?").
- *Personal/social*: comments not directly relevant to classroom activities and of a personal nature (e.g. "I saw you on the street this morning", "I have a pen like that", "Where did you get that silly hat?"). Also included in this category are requests for repetition when a comment has not been heard (e.g. "Huh?", "What did you say?", "Hm?", "Did you say "a card"?") and comments such as "Um", "Oooh" and so forth.

Note that comments such as "OK", "Yes", "Uh-huh" should be coded based on the nature of the comment that elicited this response.

<u>Feedback</u>

Record each incidence of feedback received by the observed student from a peer, teacher or other party. Note whether verbal (V) or written (W) and whether the tone of the feedback is primarily positive in nature (+), negative (-) or neutral (0). Tone of voice and gestures as well as content of comments can be used to judge which category is appropriate for verbal feedback. Examples of positive feedback: "That's a great answer", "That's not true but a good idea", "No, but not a bad try". Examples of neutral feedback: "No, try again", "That's incorrect", "That's right", "That's one reason, what about another?". Examples of negative feedback: "That's right but, knowing you, you probably just guessed that", "That's a stupid answer".

Check to whom the feedback is directed:

- *Directed at individual*: only the observed student is being addressed even if others can hear the comment.
- *Directed at pair*: the observed student and one other are being addressed.
- *Directed at small group (3-7):* the observed student and others are being addressed collectively (e.g. "Your group has been working the longest on this task.").
- *Directed at large group (8+):* the observed student and others are being addressed collectively (e.g. "Class, you really did not spend enough time on this assignment!").

<u>Type of Assignment</u>

Record the time spent on each type of assignment:

- *Listening to/watching the teacher*: observed student listens to the teacher lecture, demonstrate how to solve a problem, conduct an experiment and so forth.

- *Copying notes*: observed student copies notes from the board, overhead, textbook.
- *Working on problems/exercises*: observed student works on problems from the board, overhead, textbook, worksheet and so forth.
- *Reading assigned material*: student reads text that has been given by the teacher on paper, in a textbook, on a screen and so forth.
- *Viewing video/slides*: observed student watches video/slide material designated by the teacher.
- *Teacher-led discussion/ Q/A session*: a discussion primarily directed by the teacher who indicates who should speak and what issues to address.
- *Devising problems/tasks*: students create problems or tasks for themselves or others to work on.
- *Student-led discussion*: in such a discussion while the teacher may contribute comments, he or she is not leading by directing who should speak or which issues should be addressed.
- *Conducting experiments as per instructions*: student follows a guideline as to how to use equipment or conduct an investigation.
- *Experimenting freely*: student is allowed to use equipment to experiment without strict guidelines as to what to look for.
- *Peer tutoring*: student instructs another student for an extended period of time (several minutes).
- *Presenting*: observed student addresses others with pre-prepared comments and/or visual materials.

- *Working on a project*: observed student begins or continues with an assignment of extended nature requiring some form of research.
- *Free reading*: student reads material that he or she has identified.
- *Free writing*: student writes on a topic of his/her choosing.
- *Computer simulations/software*: student works on a computer using a simulation package or other computer software (e.g. SimCity).
- *Researching in the library/on-line*: student searches for material on a topic either in hard copy or on-line.
- *Other (specify):* student engages in some instructional activity not classified in the above categories such as setting up for an activity or packing up. Note off-task with "O/T".

<u>Grouping</u>

Check the grouping in which the student completes the assignment:

- *Independently*: student works alone;
- *In pair*: student works with one other student;
- *In small group (3-7):* student works with 3 to 7 others;
- *In large group (8+):* student works with 8 or more others;
- Can add a line for *as a whole class* underneath.

<u>Uniformity of Tasks</u>

Indicate whether the above assignment worked on by the observed student is:

- *Same for all students*;
- *Varies in academic difficulty*: tasks differ based on academic capability;

- *Varies according to student interests*: tasks differ in appeal to different interests;
- *Varies according to learning styles*: task can be completed in different ways such as writing, creating a presentation, artwork and so forth;
- *Varies in other way*: tasks vary in a manner that does not fall into the above categories (e.g. students in a group might work on different aspects of an assignment with one researching texts, another on the Internet and another preparing a display board);
- *Given by the teacher*: teacher designates what task the student will work on;
- *Selected by student from list of alternatives*: student chooses a task from a list provided by teacher;
- *Devised by observed student*: student creates his/her own task to work on;
- *Devised by other student*: student works on a task devised by another student.

Use of Resources

For each assignment noted above, note all the resources in the list below used to complete that assignment. Note whether the teacher has directed the use of the resource (T) or the student has taken the initiative to find it (S). Notebooks/notepaper in binders and writing materials (pens/pencils) are not noted as resources as it is assumed these are available in every class.

- *Teacher*: student listens to, watches, consults with the teacher;

- *Teacher-provided material on board/overhead*: student reads or copies material or works on problems provided by the teacher on board/overhead projector/slides and so forth;
- *Peers*: student consults with or works with peers;
- *Textbooks*: student reads or consults a textbook;
- *Worksheets*: student completes a worksheet;
- *Primary source documents*: student reads or consults newspapers, letters or other original documents;
- *Reference books*: student consults a reference book such as a dictionary or encyclopedia;
- *Library books/papers*: student reads or consults library books, journals and other non-primary source documents which are not the class textbook or standard reference books;
- *On-line material*: student consults/prints out text and/or graphics from on-line sources such as the Internet, World Wide Web, on-line databases;
- *Computer software*: student uses a computer software program. Note the kind of software being used (e.g. Excel, Math Blaster etc.);
- *TV/video*: student watches instructional television or video;
- *Outside experts*: student consults with outside individuals in person, via e-mail, telephone or letter. Such experts might include university professors, business people or researchers;
- *Other (specify):* student engages with a resource that does not fall into the above categories.

Notes

Indicate here any comments that may be helpful when interpreting the data such as whether the student is generally on or off task, whether discipline issues arise excessively and so forth.

Note for future use of the instrument:

A future version of this instrument could add:

1. A line to record the total number of students using a computer during the observation. Given that the number might change throughout the course of the class perhaps three counts could be taken at 10 minute intervals and then the average calculated.

2. A line to record the languages spoken during the class by the observed student.

3. In the verbal interaction section under "type of question" a line for additional types of question such as:

- *Clarification:* respondent is asked to explain an issue or a comment more clearly (e.g. "What do you mean by "evolutionary advantage"?");
- *Reporting observations:* respondent is asked to report on some visual cue (e.g. "What happened to the color of the chemical when you poured in the acid?", "What do you see on the chart?", "What date is on the fossil?");
- *Procedural:* respondent is asked a practical question relevant to the conduct of an activity currently being undertaken (e.g. "How many drops did you put in already?", "When can we connect the battery?").

4. In the grouping section a line for whole class activities.

Appendix D

TEACHING PRACTICES AND PHILOSOPHY, TEACHER ATTITUDES TOWARD COMPUTERS, TEACHER TECHNOLOGY SKILLS, AND USE IN THE CLASSROOM

This appendix reports responses to the questionnaires completed by the teachers participating in the study. The sample size is 50 for all reported items as there was no missing teacher data. The teacher questionnaire can be viewed in Appendix B.

Teaching Philosophy

Teachers were asked a series of 10 questions which were scored to obtain a measure of their teaching philosophy ranging from more traditional (low scores) to more constructivist or hands-on (high scores). The highest score possible was 56. Scores for the 50 teachers in the study ranged from 24 to 52 with a mean of 35.98. Cronbach's Alpha was calculated for the 10 items in the teaching philosophy scale in order to assess the internal consistency of the measure. The coefficient of 0.72 indicates a reliable scale.

Teaching Practices

Teachers were asked to indicate the frequency with which they employed the teaching strategies listed in Table D1 in the science class selected for participation in the study. Table D1 indicates the percent of teachers claiming to employ each strategy the indicated number of times. It is interesting to note that half or more of the teachers never grouped students by ability or assigned different activities to different students based on ability. Twenty percent never used a textbook in their classes. All the teachers indicated at least occasional use of small group work, independent work and projects.

Table D1

Percent of Teachers Claiming that they Employed the Listed Teaching Strategies with the Indicated Frequency in the Science Class Selected for Observation

Teaching strategy	Never	Occas.	1-4x/mo	5-10x/mo	Every class
Small groups	0	14	20	46	20
Independent work	0	14	20	52	14
Projects	0	22	46	26	6
Worksheets	16	18	32	26	8
Textbooks	20	20	26	26	8
Peer tutoring	6	18	32	30	14
Teacher presentations	8	8	16	32	36
Ability grouping	56	16	14	4	10
Assign different activities based on ability	50	26	12	8	4
Student presentations	12	42	38	8	0
Peer reviews of work	20	26	36	18	0
Choice in activity	16	46	34	2	2
Choice in resources	8	30	36	14	12
Students develop own activities	16	50	28	2	4
Individual verbal feedback	2	12	24	26	36
Individual written feedback	2	10	22	50	16
Synthesizing information	6	18	32	34	10
Test preparation	20	18	16	28	18

Note. Occas.= Occasionally but less than monthly; 1-4x/mo = One to four times a month; 5-10x/mo = Five to 10 times a month.

Teacher's Attitude Toward Computers

Teachers were asked a series of eight questions which were scored to obtain a measure of their attitude towards computers. A low score indicated a negative attitude towards computers and a high score implied a positive attitude towards computers. The highest possible score was 48. Scores for the 50 teachers in the study ranged from 26 to 48 with a mean of 37.10. Cronbach's Alpha was calculated for the 8 items in this scale in order to assess the internal consistency of the measure. The coefficient of 0.78 indicates a reliable scale.

Teacher's Computer Access, Use and Professional Development

Most teachers (90%) had their own computer at home, as well as a CD/ROM (88%) and Internet access (86%). Teachers were asked to note the amount of time spent per week using a computer at home and/or at school for various activities. The minimum and maximum times indicated as well as the mean for each activity are shown in Table D2. Total use of computers at home and/or at school for any purpose ranged from one hour to 64.5 hrs per week with a mean of 14.86 hours.

The amount of technology-related professional development received during the latest school year ranged from 0-36 hours with a mean of 3.15 hrs. Fifty-six percent of the teachers had received no technology-related professional development during the latest school year, 20% had received up to two hours, and 24% had received more than two hours. The average amount of technology-related professional development received by teachers in this study is low compared to the average of 20 hours reported by schools in Market Data Retrieval's (2002) national survey of public schools.

Table D2

Hours per Week Teachers Spent Using a Computer for Various Activities

Activity	Minimum	Maximum	Mean
Word processing	0	22.0	4.54
Administration	0	8.5	1.32
E-mail	0	25.0	3.43
Internet research	0	15.0	3.38
Classroom instruction	0	13.0	1.77
Use for any activity	1	64.5	14.86

Teachers had been using computers in the classroom for between 0 and 6 years with a mean of 2.14 years.

Teacher Technology Skills

Teachers were asked to rate their skills in 18 technology-related activities. Table D3 indicates how many teachers rated themselves adequate, good or excellent at the listed technology skills. Two-thirds or more of the teachers indicated adequate or better skills at word processing, research on the Internet, communication by e-mail, charts/graphing and databases/spreadsheets. Less than one-fifth rated their skills as adequate or better in web page development, video-conferencing, digital portfolio development and authoring/hypermedia development.

A technology skill score was computed for each teacher based on responses to the 18 items. The maximum possible score was 90. Scores ranged from 5 to 67 with a

Table D3

Percent of Teachers Rating Themselves as Adequate, Good or Excellent in Specific Technology Skills

Skill	% of teachers rating themselves adequate or better
Word processing	96
Research on the Internet	92
Communication by e-mail	92
Charts/graphing	76
Databases/spreadsheets	66
Subject-matter specific software/ CD/ROMs	60
Desktop publishing	54
Connecting instructional uses of technology to curriculum objectives	52
Identifying the appropriate technology for a curricular unit	44
Determining how students should be organized during technologically-enhanced instruction	42
Determining how time should be allocated during technologically-enhanced instruction	42
Presentation software	40
Technical maintenance/troubleshooting	30
Audio/video capture or digitizing	22
Web page development	18
Video-conferencing	14
Digital portfolio development	14
Authoring/hypermedia development	12

mean of 28.86. Cronbach's Alpha was calculated for the 18 items in the teacher's technology skill scale in order to assess the internal consistency of the measure. The coefficient of 0.94 indicates a very reliable scale.

Use of Computers in Classroom Instruction

Teachers were asked three different questions regarding their use of computers for classroom instruction. First, teachers were asked to indicate approximately how many hours during an average week they used computer technology as part of classroom instruction. Responses ranged from 0 to 13 hours per week with a mean of 1.77 hours. Forty percent of the teachers indicated no use of computers for classroom instruction, 36% indicated up to two hours of use, and 24% indicated more than two hours of use. Secondly, teachers were asked to indicate the degree to which computer technology is used in the classroom they had selected for observation. The responses are summarized in Table D4.

Table D4

Degree to Which Teachers Use Computer Technology in the Classroom

Use of computers in classroom	% of teachers
Not used	8
Not used but thinking about it	20
Once in a while	40
Integrated into specific instructional units	22
Fully integrated	10

Thirdly, teachers were asked to indicate the amount of time per week students spend using computers for any educational purpose in the science class. Twenty-six percent indicated their students spent no time using computers, 66% indicated up to one hour per week of student computer use, and 8% indicated more than one hour of use (see Table D5).

Table D5

Amount of Time per Week Teachers Reported their Students use Computers in Science Class

Time per week (minutes)	% of teachers indicating this amount of use
0	26
Less than 15	34
15 – 30	18
30 – 60	14
More than 60	8

The first measure differs from the others in that it refers to the teacher's entire classroom instruction whereas the other two are specific to the classroom selected for study participation. However, even accounting for this difference the first measure does not appear consistent with the other two. The last two measures do demonstrate consistency.

Teachers indicated that students used technology in the science class for a variety of activities summarized in Table D6. The most common use was researching on the Internet followed by using word processing software.

Table D6

Technology Uses in the Science Classroom

Activity	% of teachers indicating that students engaged in this activity in science class
Internet research	72
Word processing	58
Video/TV	46
Graphing/scientific calculators	38
CD/ROM research	38
Using presentation software	22
Desktop publishing or graphics	22
Databases	22
Spreadsheets	22
E-mailing peers	20
Drill/practice software	18
Interactive video	18
E-mailing experts	12
Videodisks	12
Creating web pages	10

Teachers were asked how much time per week students in the class selected for observation spent engaging in the technology-using activities listed in Table D7. Activities are ranked in ascending order based on the percent of teachers who indicated no time spent on that activity. This roughly translates into the most common activities being at the top of the list.

Table D7

Percent of Teachers Claiming that their Students Spent the Indicated Number of Minutes (Mins) per Week during Science Class Engaging in Technology-related Activities

Activity	No time	Less than 15 mins	15-30 mins	30-60 mins	More than 60 mins
Doing research using the Internet	28	22	24	12	14
Using word processing software	42	26	18	10	4
Viewing videotapes or television in a non-interactive environment	54	28	16	0	2
Using graphing/scientific calculators	62	18	14	4	2
Doing research using CD/ROMs	62	22	6	6	4
Creating/sharing presentations using presentation software	78	10	2	4	6
Using desktop publishing or graphics software	78	6	6	4	6
Creating/managing/analyzing databases	78	12	6	2	2
Creating/managing/analyzing spreadsheets	78	12	2	6	2
Using e-mail to communicate with peers for educational purposes	80	10	4	2	4
Using content-related programs for drill and practice	82	4	10	4	0
Participating in an interactive video environment	82	10	6	2	0
Using e-mail to communicate with experts for educational purposes	88	4	6	2	0
Viewing videodisks in an interactive video environment	88	6	6	0	0
Creating/maintaining web pages	90	4	0	4	2

Differences Computers and Other Technology Make to Teaching

Teachers were asked, in an open-ended question, to describe what difference computers and other technology made to their teaching. The responses are summarized in Table D8, and examples of the teacher comments are listed below for some categories.

Table D8

Differences Computers and Other Technology Make to Teaching

Change	% of teachers mentioning this
Better access to resources	40
Changes way student work is executed/organized/presented	38
Increases student interest/motivation	14
Facilitates administration and communication	8
Changes teacher's role	6

Examples of responses regarding better access to resources: more/better resources available to teacher/students; presents concepts in a different way, serves different learning models, for example, visual images; allows for extensions/enhancement of lesson topics; facilitates research via Internet and from encyclopedias.

Examples of changes computers lead to in the way student work is executed, organized or presented: allow for different activities such as word processing, web page design, hyperstudio projects, databases, portfolios, concept-mapping; facilitate data processing and analysis; provide a hands-on activity; improve student products e.g., easy to create original work; facilitate individual/small group work/projects; encourage peer tutoring/interaction and collaboration; get more excuses from students related to the computer not working, Internet access being down and so forth; harder to account for students' work and ensure it is original rather than copied from a website, for example.

Examples of change in the teacher's role caused by computer use in the classroom: forces teacher to rethink how to conduct group-work and lessons; teacher becomes more of a mediator; teacher takes on technical troubleshooting role.

While not a formal part of data collection, a conversation with one technology teacher who worked with a science teacher on projects for students in Grade 8 produced the following quote that highlights some other differences:

> Students can't listen and be at the computer at the same time. It must be all hands-on. They write so much. I haven't seen them write this much all year. They get the work done much more slowly but they are more engaged. You [the teacher] just float around and help them at their different levels. They work at different paces but at least everyone produces something. Students love having the choice of doing an assignment on paper or on a computer.

Appendix E

STUDENT CONSENT LETTERS AND QUESTIONNAIRE

PARENT/STUDENT CONSENT LETTER

220 West 93rd Street, #14B
New York, NY 10025

12 September 2000

Dear Parent/Guardian and Student,

I am a doctoral candidate at Teachers College, Columbia University and am planning to observe a number of students in New York City classrooms to investigate how the presence or absence of technology, such as personal computers, has affected teaching and learning in science classes.

Participants will be asked to complete the enclosed questionnaire regarding technology use and skills as well as classroom activities. Completion should take 5-10 minutes. At a later date they will be observed during the regular course of a lesson. Observations will focus on the nature of verbal interactions, how resources are used and the type of assignments being worked on. An audiotape may be used with your permission so that verbal interactions can be analyzed for length, content and frequency. Any such tapes will be destroyed once the research is complete. The student's teacher or a school administrator will be asked for grades and standardized test scores for the student simply for the purpose of assuring a representative sample of student abilities. The observation will not interfere with the students' activities during class time.

All information will remain anonymous and confidential. Participation in this study is entirely voluntary and participants may withdraw at any time, with no consequences. Please feel free to call me on 212 362 9227 with any questions or concerns. Additionally, if you have any concerns regarding this study you may contact the Institutional Review Board at Teachers College, Columbia University, 212 678 4105 or 525 W 120th Street, New York NY 10027, Box 151.

Please return this letter in the envelope provided indicating whether or not you agree to let your child participate in this study. In addition to your signature, please ask the student to read the letter and sign his/her consent. If you have agreed to participation, please return the completed questionnaire in the envelope provided.

Thanking you in advance

Yours sincerely

Fiona Hollands

I agree/do not agree to let my child____________________________ participate in the above study

Signed ______________ (parent/guardian) Date: ________

PRINT NAME ______________

Signature of **student**:_______________ Date: ________

Signature of **investigator**: __________________ Date: ________

Teachers College, Columbia University
Assent Form for minors (8-17 years old)

I ....agree to participate in the study entitled:

A comparison of high and low technology classrooms with respect to the individualization of students' learning experiences.

The purpose and nature of the study has been fully explained to me by **Fiona Hollands. I understand what is being asked of me and, should I have any questions, I know that I can contact Fiona Hollands at any time. I also understand that I can quit the study any time I want to.**

Name of Participant:...

Signature of Participant:..

Witness:...

Date:...

Investigator's Verification of Explanation

I certify that I have carefully explained the purpose and nature of this research to... in age-appropriate language. He/She has had the opportunity to discuss it with me in detail. I have answered all his/her questions and he/she provided the affirmative agreement (i.e. assent) to participate in this research.

Investigator's Signature:..

Date:..

STUDENT QUESTIONNAIRE
Student code #

Thank you for agreeing to participate in this study. Please complete the following questionnaire and return it in the envelope provided. This header sheet with your name will be removed upon receipt and a code number placed on your answers so that your responses remain completely confidential.

1. Name:___________________________

STUDENT QUESTIONNAIRE
Student code #

2. School: ______________________________

3. Science Teacher: ______________________________

4. Your age in years
(circle one): 10 11 12 13 14 15 16 17 18

5. Grade *(circle one)*: 6 7 8

6. Gender *(circle one):* Male Female

7. Racial/ethnic background *(circle one)*

African-American Asian-American Latino

Native American White Multiracial

Other_________

8. How many schools have you attended since kindergarten? ____________

9. Please indicate your parents' highest level of education *(check one box in each column):*

	Mother	**Father**
Eighth grade or less	☐	☐
Some high school	☐	☐
High school graduation or GED	☐	☐
Vocational, trade or business school	☐	☐
Some college	☐	☐
2 year college degree	☐	☐
4 or 5 year college degree	☐	☐
Master's degree or equivalent	☐	☐
Ph.D., M.D. or other advanced degree	☐	☐

STUDENT QUESTIONNAIRE
Student code #

10. How old were you when you first began to use a computer? *(circle one)*

2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 DON'T USE ONE

11. Where do you use computers and how often? *(check one box in each row)*

	Never	Less than once a month	1-3 times a month	1-3 times a week	Every day
At home					
At school in classrooms					
At school in computer lab					
At school in library					
At public library					
Other ________					

12. Check any of the following activities you can do without help on a computer:

- ☐ play games (educational or entertainment)
- ☐ visit a chat room
- ☐ type a homework assignment
- ☐ surf the Internet and Worldwide Web
- ☐ e-mail
- ☐ conduct research on the Internet
- ☐ conduct research on a CD/ROM
- ☐ create a website
- ☐ create a presentation
- ☐ use a graphics package
- ☐ create a spreadsheet
- ☐ create a database
- ☐ use educational software

STUDENT QUESTIONNAIRE
Student code #

13. Please name any software programs that you have used:

_______________ _______________ _______________

_______________ _______________ _______________

_______________ _______________ _______________

14. How many years ago did you start using a computer at school? (Circle one item)

1 2 3 4 5 6 7 8 9 10 11 12 13 14 JUST STARTED THIS YEAR

15. In your SCIENCE class this semester how often do you use a computer? *(circle one)*

NEVER 1-3 TIMES /MONTH 1-3 TIMES /WEEK EVERY CLASS

[If NEVER, skip to question 20].

16. Please name any software used in SCIENCE class this year

_______________ _______________

_______________ _______________

_______________ _______________

17. What do you use a computer for in SCIENCE class *(check all that apply)*

☐ play games (educational or entertainment)
☐ visit a chat room
☐ type a homework assignment
☐ surf the Internet and Worldwide Web
☐ e-mail
☐ conduct research on the Internet
☐ conduct research on a CD/ROM
☐ create a website
☐ create a presentation
☐ use a graphics package
☐ create a spreadsheet
☐ create a database
☐ use educational software
other *(please describe)*: ....

STUDENT QUESTIONNAIRE
Student code #

18. a) Overall, do you think having computers and other technology in the SCIENCE class makes any difference to how you learn? ***(Circle one)***

YES NO

b) If YES, then please describe these differences:

....

....

....

19. When you use a computer in SCIENCE class are you usually working *(circle one)*

ALONE WITH ONE OTHER STUDENT WITH A GROUP OF STUDENTS WITH TEACHER

20. In SCIENCE class do you feel you get more or less individual attention for academic instruction from the teacher than in other classes at school? *(circle one)*

MORE LESS SAME DON'T KNOW

21. In SCIENCE class do you feel you have more or less opportunity to interact with your peers for academic purposes than in other classes? *(circle one)*

MORE LESS SAME DON'T KNOW

22. In SCIENCE class do you feel you get more or less feedback on your work than in other classes? *(circle one)*

MORE LESS SAME DON'T KNOW

23. How much choice do you get in what assignment you work on in SCIENCE class? *(circle one)*

A LOT QUITE A BIT SOME NOT MUCH NONE

24. Is every student in the SCIENCE class assigned the same work? *(circle one)*

ALWAYS USUALLY SOMETIMES NEVER

STUDENT QUESTIONNAIRE
Student code #

25. Once you have an assignment in SCIENCE class, how much choice do you get in choosing which resources to use for completing it (i.e. whether to use a textbook, go to the library, use the Internet etc.) *(circle one)*

A LOT QUITE A BIT SOME NOT MUCH NONE

THANK YOU FOR YOUR TIME!

Appendix F

STUDENTS' USE OF COMPUTERS AND STUDENT-REPORTED CLASSROOM ENVIRONMENT

This appendix summarizes the responses to the 673 student questionnaires, completed by students of the 50 teachers participating in the study, regarding student use of computers and the classroom environment. The sample size is 673 for all statistics unless otherwise indicated. The student level data did have some missing data. The student questionnaire may be viewed in Appendix E.

Student Computer Use

Students were asked when they first began to use computers. The youngest age reported was 2 years and the oldest was 14 years with a mean of 7.43 years (N = 672). Every student had used a computer at some point. Students were asked to check the locations at which they used a computer and frequency of use at this location. Table F1 summarizes where computers were used and indicates that most frequent use was at home or in the classroom. Table F2 indicates frequency of use at each location.

As illustrated in Table F2, computer use in classrooms and computer laboratories was most likely to be 1-3 times a week although, overall, computer use in the classroom was more frequent than in computer laboratories. This may reflect a strategic move by educators to integrate computers into regular classroom instruction. It is curious to note that students used computers more often in public libraries than in school libraries. A technology use score was assigned to each student based on the frequency of computer use in all six possible categories with a maximum possible score of 24. Scores for the sample ranged from 1 to 23 with a mean of 9.7. Cronbach's Alpha was calculated

Table F1

Where Students Use Computers

Where students use computers	% of students reporting this location
At home (N = 671)	83.3
Classrooms	82.6
School computer laboratory (N= 671)	69.7
Somewhere else* (N = 605)	64.3
Public library (N = 670)	61.5
School library (N = 670)	39.7

*A parent's office, community center, friend or relative's house, after-school program.

Table F2

Percentages of Students Indicating Computer Use in Different Locations at Various Frequencies

Locations of Computers	Never	Less than once a month	1-3 times/ month	1-3 times/ week	Every day
At home (N = 671)	16.7	4.6	6.1	26.4	46.2
In classroom (N = 673)	17.4	15.9	17.2	37.7	11.7
Comp. lab (N= 671)	30.3	9.7	11.6	42.2	6.3
School library (N = 670)	60.3	23.1	11.0	4.2	1.3
Public library (N = 670)	38.5	32.1	20.4	6.1	2.8
Somewhere else* (N = 605)	35.7	14.5	23.8	21.2	4.8

Note. Comp. lab = school computer laboratory. *A parent's office, community center, friend or relative's house, after-school program.

for the 6 items in the technology use scale. The coefficient of 0.33 indicates fairly low reliability of the scale tempering its usefulness. However, it is not surprising that students who used a computer often at home did not necessarily do so at school and vice versa.

Students were asked how many years ago they began to use a computer in school. Only one student had never used a computer in school, 19.2% had started in the last two years, 53.4% had started three to five years ago, and 27.3% had started six or more years ago (10 years ago was the maximum response given). On average, computer use in school started 4.3 years ago. By taking the difference between the student's age and number of years ago that computer use was begun in school, the actual age at which computer use began in school was calculated. It appears that students started using computers in school as young as 3 years and as old as 13.5 years (other than the one student who had never used a computer in school) with mean age of 8.18 years. Eighty-five percent of the students had used a computer in school before age 11, that is, before entering middle school. Most students started using computers in school between ages 5 and 10.

Students were asked to check off items on a list of 13 activities indicating which they could do without help on a computer. Responses are indicated in Table F3. Three quarters or more of the students could play educational or entertainment games, type a homework assignment, surf the Internet and Worldwide Web and conduct research on the Internet without help. Less than one third of the students could create a database or website without help.

Table F3

Percent of Students Reporting the Ability to Execute Specific Activities Without Help on a Computer

Activity	% able to execute activity
Play educational or entertainment games	96.9
Type a homework assignment	90.9
Surf the Internet and Worldwide Web	81.4
Conduct research on the Internet	75.3
Use educational software	67.2
E-mail	65.4
Visit a chat room	61.2
Conduct research on a CD/ROM	58.4
Create a presentation	47.7
Create a spreadsheet	40.0
Use a graphics package	34.0
Create a database	29.3
Create a website	28.4

Students were assigned a score out of 13 for the number of activities they checked. The mean for this student technology skill score was 7.76. Cronbach's Alpha was calculated for the 13 items in the student's technology skill scale in order to assess the internal consistency of the measure. The coefficient of 0.81 indicates a reliable scale.

Students were asked in an open-ended question to list any software they had used. Applications mentioned by 5% or more of the students are listed in Table F4. A third or more of the students listed Microsoft Word, Netscape, entertainment games,

Table F4

Computer Software Used by at Least 5% of the Students

Software (N=645)	% of students listing this software
Microsoft Word	56.6
Netscape	39.8
Entertainment games	38.8
Internet Explorer	35.2
Clarisworks	33.8
Encarta Encyclopedia	23.9
Hyperstudio	20.6
Powerpoint	19.8
Appleworks	19.7
Excel	16.9
Kidpix	11.6
Microsoft Publisher	10.2
Grolier Encyclopedia	8.4
Microsoft Works	7.6
Student Writing Center	5.7
Math Blaster	5.1

Internet Explorer and Clarisworks. Most applications in the list are tools rather than content-specific software, with the exception of entertainment games, encyclopedias, and Math Blaster. E-mail programs were not tabulated. It should be noted that many students did not understand the question until examples of software were given to them. Even then some students (4%) either claimed they did not know the names of any software they used or simply left the question blank.

Computer Use in Science Class

Students were asked to indicate how often they used a computer in science class. In Table F5, responses are compared with the frequency of use in classrooms as a whole. Fifty-two percent of the students indicated that they never used a computer in science class, 22.9% indicated one to three times a month, and the remaining 25.2% indicated using computers weekly or in every science class. Clearly many students who are using computers in a classroom at school are not doing so in science. This study did not ask in which classes computers were used most and a future study should do so. However, from observations and conversations with teachers, principals and students as well as from existing studies (e.g. Becker, Ravitz, & Wong, 1999), it appears that language arts and social studies classrooms more often incorporate computers into learning activities.

Table F5

Percent of Students Using Computers in Science Class at Different Frequencies Compared with Computer Use in Classrooms as a Whole

Frequency of computer use	In science class	In classrooms as a whole
Never	52.0	17.4
Up to 3 times a month	22.9	33.1
1-3 times a week	20.7	37.7
Every class	4.5	11.7

Students were asked to check the activities they used a computer for in science class. As indicated in Table F6, over half the students used computers in science class for research on the Internet, surfing the Internet and Worldwide Web and typing a homework assignment. Additional uses mentioned by students in an open-ended question included doing projects, downloading science programs, creating slideshows, taking notes, doing class work, creating graphs, and watching movies.

Table F6

Percent of Students Reporting Computer Use for Specific Activities in Science Class

Activity (N = 322)	% of students
Conduct research on the Internet	72.0
Surf the Internet and Worldwide Web	65.8
Type a homework assignment	62.7
Use educational software	43.5
Create a presentation	38.2
Conduct research on a CD/ROM	36.0
Create a spreadsheet	26.1
Play educational or entertainment games	23.6
Create a database	15.2
Create a website	13.0
Use a graphics package	12.4
E-mail	9.6
Visit a chat room	4.3

Students who used computers in science class were asked whether they thought that having computers and other technology in the science classroom made any difference to how they learn. Seventy-five and nine-tenths percent (N = 323) responded affirmatively and, in response to an open-ended question, many of them provided reasons that are summarized in Table F7. The two commonest reasons given were an increase in the amount of information available and easier or faster access to information and execution of tasks.

Table F7

Ways in Which Students Claim Computers and Other Technology Make a Difference to How They Learn

Difference made by computers and other technology (N=242)	% of students mentioning this
More information available (increases scope of research activities, enhances material being taught, provides visual images)	40.5
Allow easier/faster access to information and execution of tasks	32.2
Allow students to learn things that they could not learn otherwise, explore and present material differently, clarify things being taught	23.1
More fun/interesting/hands-on	11.6
More relevant to real life/work life, students learn useful skills	7.9
Improve presentation of work	7.1
Facilitate communication, interaction with peers, peer tutoring	2.1
Improve the organization of work	1.7

Students were asked with whom they were most likely to work when using a computer in science class. Fifty-two and five-tenths percent responded that they were most likely to be working alone, 27.3% indicated that they were most likely to be working with one other student, 18.6% with a group of students, and 1.6% with the teacher (N = 322).

Students who used a computer in science class were asked to name any software used in the science class. Applications listed by 5% or more of the respondents are shown in Table F8. The three most often named software titles used in science class were Netscape, Microsoft Word, and Internet Explorer. These responses are supported by

Table F8

Software Used by More than 5% of Computer-using Students in the Science Class

Software (N=315)	% of respondents using this software in science class
Netscape	44.4
Microsoft Word	30.5
Internet Explorer	28.3
Clarisworks	22.2
Appleworks	20.0
Hyperstudio	18.1
Excel	12.1
Powerpoint	11.4
Encarta Encyclopedia	9.5
Microsoft Publisher	7.6
Grolier Encyclopedia	6.0
Student Writing Center	6.0
NASA Software	5.1

the activities students indicated they used computers for in the science classroom and also by classroom observations. Netscape and Internet Explorer were commonly used for Internet research. Word, Clarisworks, and Student Writing Center were used for typing assignments. Encarta and Grolier Encyclopedias were the most commonly used reference tools. Appleworks, Hyperstudio, and Powerpoint were used to create presentations. While use of Excel was not observed, teachers and students explained that they used the program for data input, analysis, and graphing. Microsoft Publisher was used for desktop publishing.

It is notable that the most commonly used software programs were tools rather than specific science content software. NASA software appears due to its use in one particular school. Other content programs mentioned by fewer than 5% of the students included Neuron, Holt Earth Science, Microworlds, and Zoombinis.

Classroom Learning Environment

The last few questions asked students about their learning experiences in the science classroom, some compared to other classes at school and some just relevant to science itself. The purpose of these questions was to specifically address the study hypotheses about how the use of technology in the classroom might affect the process of teaching and learning. The questions deliberately did not ask the students to make the link between technology and these indicators. These relationships were later investigated by statistically analyzing whether and how responses to these questions differed among students using computers at different frequencies in the science class.

Q. In science class do you feel you get more or less individual attention for academic instruction from the teacher than in other classes at school?

Sixty and nine-tenths percent of the students indicated the same amount of attention, 15.9% more attention, and 8.3% less attention. Fourteen and six-tenths percent of the students did not know (N = 671).

Q. In science class do you feel you get more opportunity to interact with your peers for academic purposes than in other classes?

Forty-four and three-tenths percent of the students reported the same level of interaction, 29.4% more interaction, and 10.8% indicated less. Fifteen and two-tenths percent did not know (N = 671).

Q. In science class do you feel you get more or less feedback on your work than in other classes?

Fifty and one-tenths percent reported the same amount of feedback, 22.7% reported more feedback, and 15.3% less feedback. Eleven and nine-tenths percent did not know (N = 673).

Q. How much choice do you get in what assignment you work on in science class?

Fourteen and three-tenths percent of the students reported no choice in assignment, 31.5% not much choice, 26.9% some choice, 18.9% quite a bit of choice, and 8.3% indicated a lot of choice (N = 672).

Q. Is every student in the science class assigned the same work?

Forty-nine and eight-tenths percent of the students reported always being assigned the same work, 35.8% usually, 13.8% sometimes, and 0.06% never (N = 673).

Q. Once you have an assignment in science class, how much choice do you get in which resources to use for completing it (i.e., whether to use a textbook, go to the library, use the Internet, etc.)?

Thirty-six and three-tenths percent of the students reported having a lot of choice in resources, 20.4% quite a bit of choice, 26.3% some choice, 10.8% not much choice, and 6.2% no choice at all (N = 673).

For the purposes of statistical analysis, these six outcomes were recoded into three response categories in each case. While for the last three questions this involved only collapsing the response categories, for the first three the "don't know" response was omitted by recoding these entries as missing. Actual missing responses were non-existent or negligible for all six outcomes. The "don't know" or missing responses were checked for any obvious bias that this tactic introduced into the remaining data. For the individual attention question, 14.6% of the students responded "don't know". From correlation statistics it appears that students giving this response were more likely to be younger than those giving a different response. For the peer interaction question, 15.2% of the students responded "don't know". These students, compared with students giving a different response, were more likely to be in lower grades, have lower math and reading scores and to have moved schools more often. For the feedback question, 11.9% of the students responded "don't know". These students were more likely to have moved schools more often than students giving different responses. It appears, in general, that the "don't know" responses were more likely to be selected by younger, lower achieving students of lower socio-economic status so that these students are under-represented in the recoded dataset. It is probable that these students simply did not fully understand the questions, highlighting the reliability problems associated with the collection of self-report data.

Appendix G

CORRELATIONS BETWEEN STUDENT-REPORTED FREQUENCY OF COMPUTER USE AND STUDENT, TEACHER, CLASSROOM AND SCHOOL VARIABLES

The major independent variable under investigation in the student questionnaire data was the frequency of computer use in the science class. Students were asked to indicate how often they used a computer in the science class. Possible responses were: never, one to three times a month, one to three times a week and every class. The last two categories were collapsed into one for data analysis purposes as few students reported using computers in every class. Correlations with the other variables in the various datasets (student questionnaire data, teacher questionnaire data and school data) were run to determine which factors were associated with computer use and which of the indicators of individualized instruction (e.g. number of interactions, amount of feedback etc.) might be related to degree of computer use. These correlations are reported in this appendix.

In all correlation tables shown, ** indicates that the correlation is significant at the .01 level (2-tailed) and * indicates that the correlation is significant at the .05 level (2-tailed). The sample size is 673 for all statistics unless otherwise indicated.

As an initial check on validity of the data collected regarding frequency of computer use, it was found that the student-reported frequency of computer use correlated significantly with the teacher's report of computer use ($r\ (673) = .65, p < .01$) and the teacher's claim on the extent to which computer technology was integrated in the classroom ($r\ (673) = .60, p < .01$).

A significant positive association was found between frequency of computer use and the number of questionnaires returned per classroom (r (673) = .23, p < .05). This indicates that students who used computers more often in class were more likely to return the questionnaires.

Student Demographics

Computer use did not vary significantly by gender, age, grade or race as indicated in Table G1.

Table G1

Correlations between Frequency of Computer Use and Student Demographics

	Gender	Age	Grade	White	Latino	African-American	Other Race
Frequency of computer use	-.01	.02	.03	.02	.06	-.07	-.03

Note. The four different race categories indicated were dummy coded. For gender, female is coded 1, male 0.

There was no association between frequency of computer use in class and student's mother's education level (r (633) = -.05, p > .05), student's father's level of education (r (547) = .03, p > .05) or the number of schools attended by students since kindergarten (r (672) = .04, p > .05).

Students with higher grade point averages, science grades and standardized math test scores reported using computers with greater frequency as shown in Table G2.

Table G2

Correlations between Frequency of Computer Use and Achievement Scores

	GPA	Science grade	Reading score	Math score
Frequency of computer use	.12**	.20**	.06	.10*
	N = 667	N = 671	N = 612	N = 625

Student Computing Experience

Students with higher technology skill scores and those who used computers more often both in and out of school also indicated the greatest frequency of use in science class (see Table G3). Age at which students began to use a computer anywhere and age at which computer use started at school were not associated with frequency of computer use in the science class.

Table G3

Correlations between Frequency of Computer Use and Computing Experience

Computing experience	Frequency of computer use
Age at which student first used a computer (N = 672)	.04
Student's technology skill score	.17**
Score of student's overall computer use in and out of school	.27**
Number of years ago student started to use a computer at school	-.04

Students who used computers more often were more likely to indicate that having computers and other technology in the science class made a difference to how they learned (r (323) = .14, $p < .05$).

Teacher Demographics

As indicated in Table G4, students of female teachers used computers more frequently than those of male teachers. Students of White teachers used computers less frequently than students of other teachers. Students of Latino or African-American teacners used computers more often than students of other teachers. Note, however, that female teachers in the study were also more constructivist and more often were Latino or African-American so that these three variables are closely interconnected.

Table G4

Correlations between Frequency of Student Computer Use and Teacher Demographic Variables

	Gender	White	Latino	African-American	Other
Frequency of computer use	.23**	-.23**	.08*	.20**	.03

Note. Race categories are dummy coded. For gender, female is coded 1, male 0.

Frequency of computer use reported by students was not associated with the number of years the teacher had been teaching (r (673) = -.06, p > .05) or the teacher's age (r (673) = .00, p > .05). However, students of teachers with higher levels of education used computers less frequently (r (673) = -.11, p < .01). However, note that participating White teachers generally had higher levels of education than others so that ethnicity and education are closely interconnected teacher variables. Students of more constructivist teachers used computers more frequently than those of more traditional teachers (r (673) = .40, p < .01).

Teachers' Computing Experience and Skill

Frequency of student computer use was positively associated with all aspects of the teacher's computing experience and skill as indicated in Table G5: the teacher's attitude toward computers; the teacher's possession of a computer at home; the amount of time the teacher used computers per week for any purpose; the number of hours of technology-related professional development the teacher had received during the school year; the teacher's technology skill score; and the number of years the teacher had been using computer technology in the classroom.

Table G5

Correlations between Frequency of Computer Use and Teacher's Computing Experience and Skill

Teacher variable	Frequency of computer use
Teacher's attitude score towards computers	.41**
Teacher's possession of a home computer	.09*
Total number of hours per week teacher spends on a computer for any purposes	.40 **
Number of hours of technology-related professional development received during the school year	.47**
Teacher's technology skill score	.44**
Number of years teacher has been using computer technology in the classroom	.19**

Teaching Strategies

As indicated in Table G6, positive associations were found between computer use and the teacher-reported frequencies of a number of teaching strategies: small group activities; project work; student oral presentations; students reviewing/discussing the

Table G6

Correlations between Frequency of Computer Use and Teaching Strategies

Teaching Strategy	Frequency of computer use
Small group activities	.16**
Independent work	-.18**
Project work	.42**
Worksheet use	-.30
Textbook use	.22**
Peer tutoring	-.18**
Teacher presentations	-.12**
Grouping by ability	.01
Assigning different activities based on ability	.03
Student oral presentations	.38**
Students reviewing/discussing other students' work	.22**
Students given choice in activity based on interest	.37**
Students given choice in resources used	.09*
Students develop own learning activities	.01
Individual verbal feedback given to students	.10*
Individual written feedback given to students	.06
Students synthesize information from a variety of sources	.26**
Activities to improve students' standardized test scores	-.08*

work of other students; allowing students a choice in activity based on interest; allowing students a choice among resources; giving individual verbal feedback to students on work and having students synthesize information from a variety of sources. On the other hand, the following teaching strategies were associated with less frequent use of computers: assigning independent work; use of worksheets; use of textbooks; peer tutoring; teacher presentations; test preparation activities. Note that while most of these associations were supported by the observation data, others were not. For example, students using computers were most often observed working independently and less often in small groups. Students using computers were not observed receiving more feedback on their work than students not using computers.

Classroom Variables

Larger class size was associated with less frequent computer use (r (673) = -.11, $p < .01$). Frequency of computer use was not associated with the number of times per week the science class met (r (673) = .05, $p > .05$) or the total amount of time per week the class met (r (673) = .08, $p > .05$). Students in regular track classrooms used computers less frequently than students in other types of class whereas those in accelerated/honors classrooms and "other" classrooms (special education, electives etc.) used them more as indicated in Table G7.

Table G7

Correlations between Frequency of Computer Use and Type of Class

Class type	Frequency of computer use
Regular track class	-.22**
Accelerated or honors class	.11**
Bilingual class	.06
Other class type	.23**

Note. Class type categories were dummy coded.

Students studying Life Science used computers more frequently than students in classrooms following other curricula (r (673) = .20, p < .01) whereas students studying Physical Science used computers less (r (673) = -.13, p < .01). Students studying some combination of Earth, Life and/or Physical Science also used computers less frequently (r (673) = -.08, p <.05). There was no association between computer use and Earth Science (r (673) = .03, p > .05). Students who were required to take a standardized science test during the school year reported less frequent use of computers than students not required to take a standardized test (r (673) = -.21, p < .01).

Frequency of computer use was positively related to hardware availability. Greater frequency of computer use was reported by students in classrooms with more working computers (r (673) = .52, p < .01) and with more working Internet connections (r (673) = .48, p < .01).

School Variables

There was no association between the total number of students in a school and frequency of student computer use (r (673) = -.05, p > .05). Although frequency of computer use was unrelated to the actual number of teachers (r (673) = .05, p > .05), a smaller student/teacher ratio was associated with more frequent use (r (673) = -.35, p < .01). In schools with larger numbers of students in Grade 6, frequency of computer use was lower (r (673) = -.09, p < .05). Frequency of computer use was unrelated to the numbers of students in Grade 7 (r (673) = .03, p > .05) and Grade 8 (r (673) = -.04, p > .05).

Table G8 indicates correlations between frequency of student computer use and the demographics of the student body. Students in schools with a higher percentage of boys indicated less frequent use of computers while the opposite was true for students in schools with a higher percentage of girls. There was no association between frequency of computer use and percentages of English Language Learners, Special Education students or students receiving free lunch. Computer use was positively associated with the percentage of Hispanic students in the school and negatively associated with the percentage of Asian or Other students, the percentage of African-American students and the percentage of White students.

Table G8

Correlations between Frequency of Computer Use and Demographics of the Student Body

Student body variable	Frequency of computer use
% boys	-.11**
% girls	.11**
% eligible for free lunch	.04
% English Language Learners	.06
% Special Education	.02
% African-American	-.17**
% Hispanic	.26**
% White	-.09*
% Asian or other	-.15**

Computer use was more frequent in schools with higher scores on the Grade 8 English Language Assessment test (r (673) = .14, p < .01) and on the Grade 8 Mathematics test (r (673) = .20, p < .01).

Computer use was more frequent in schools benefiting from more technology initiatives ($r\ (673) = .40, p < .01$), in those participating in a Technology Innovation Challenge Grant project ($r\ (673) = .16, p < .01$) and in those with a dedicated technology person in the school ($r\ (673) = .29, p < .01$).

Appendix H

CORRELATIONS BETWEEN AMOUNT OF TIME STUDENTS ARE OBSERVED USING A COMPUTER AND STUDENT, TEACHER, CLASSROOM, AND SCHOOL VARIABLES

The major independent variable under investigation in the observation data was the amount of time the observed student spent using a computer during the 30 minutes observed (TIMCOMP). Correlations with other variables in the various datasets (observation data, student questionnaire data, teacher questionnaire data and school data) were run to determine which factors were associated with computer use and which of the outcome variables (e.g. number of interactions, amount of feedback etc.) might be related to degree of computer use.

In all correlation tables shown, ** indicates that the correlation is significant at the .01 level (2-tailed) and * indicates that the correlation is significant at the .05 level (2-tailed). The sample size for all statistics is 191 unless otherwise indicated.

As an initial check on the validity of the data collected regarding computer use, it was found that the amount of time students were observed using a computer correlated significantly with the students' questionnaire responses regarding frequency of computer use in the science class (r (191) = .65, $p < .01$). Additionally, the amount of time students were observed using a computer correlated positively with the teacher's report of computer use (r (191) = .70, $p < .01$) and the teacher's report regarding the extent to which computer technology is integrated in the classroom (r (191) = .62, $p < .01$).

The correlation between amount of computer use observed and the number of student questionnaires returned per classroom was also checked given the earlier finding that more student questionnaires were returned from classrooms where students indicated more frequent computer use. There was no significant association between observed computer use and number of questionnaires returned (r (191) = .11, $p > .05$).

Students observed later in the school year used a computer longer than those who were observed earlier (r (191) = .21, $p < .01$). This correlation is partly attributable to the order in which the observer visited schools and classrooms (unintentionally, more computer-using classrooms were visited later in the school year) and partly due to the fact that students were likely to use computers for science fair projects which were often worked on towards the end of the academic year.

There was no correlation between amount of computer use and the identity of the observer (r (191) = .05, $p > .05$). This supports the objectivity of the data.

Student Demographics

Amount of computer use did not vary significantly by gender or age of students as shown in Table H1. However, students in higher grades used computers longer. Students who spoke Spanish or a mix of Spanish and English during the observation used computers longer than those who spoke only English. Concomitantly, Latino students used computers longer than students of other racial groups. African-American students and those in the "other" race category used computers less. Note that more students in the higher grades observed were Latino so these effects may be confounded.

Amount of computer use time was not associated with the student's grade point average (GPA) (r (191) = .10, $p > .05$), latest science score earned in class (r (191) = .14, $p > .05$), standardized reading score (r (191) = -.08, $p > .05$) or standardized mathematics score (r (191) = -.11, $p > .05$).

Table H1

Correlations between Time on Computer and Student Demographics

	Gender	Age	Grade	Language	White	Latino	African-American	Other Race
Time on computer	.09	.11	.18*	.23**	-.12	.35**	-.19**	-.17*

Note. Language spoken by the observed student during the observation was coded 0 for English and 1 for Spanish or a mix of Spanish and English; the four different race categories indicated were dummy coded. For gender, female was coded 1, male 0.

There was no association between the number of schools the students had attended since kindergarten and the amount of computer use in class (r (191) = .03, p > .05). However, students whose mother had higher levels of education used computers less in class (r (191) = -.31, p < .01) as did students whose father had higher levels of education (r (191) = -.18, p < .05).

<u>Student Computing Experience</u>

Students who began using a computer at a later age also used a computer more in science class as shown in Table H2. There was no association between computer use and the student's technology skill score, the overall amount of computer use in and out of school or the number of years the student had been using a computer in school.

<u>Verbal Interactions</u>

Students who used computers for more time engaged in fewer verbal interactions than those who used a computer less (r (191) = -.16, p < .05). However, the student's number of turns did not differ significantly with length of computer use (r (191) = -.02, p > .05) although the number of turns per interaction was greater as computer use time increased (r (191) = .16, p < .05). It appears that although students using computers

Table H2

Correlations between Time on Computer and Computing Experience

Computing experience	Time on computer
Age at which student first used a computer	.17*
Student's technology skill score	.14
Score of student's overall computer use in and out of school	.08
Number of years ago student started to use a computer at school	-.11

interacted less often with others in the classroom, when they did, those interactions were more protracted so that the overall number of turns counted for the student did not differ.

Amount of time on the computer was not related in any significant way to the type of counterparty (teacher/peer/administrator/other) with whom a student conversed as shown by Table H3. However, it is notable that students who had a greater percentage of interactions with peers showed a smaller percentage of interactions with the teacher (r (191) = -.93, p < .01).

Students who used computers more time engaged in more one-on-one verbal exchanges with counterparties and fewer whole group exchanges than those who used computers less as indicated by Table H4.

Students who used computers for more time engaged in more one-on-one interactions with the teacher than those who used computers less, both in absolute and percentage terms as shown in Table H5.

Table H3

Correlations Between Time on Computer and Frequency or Percentage of Interactions with Different Counterparties

Counterparty	Time on computer
Frequency of interactions with teacher	-.02
% of interactions with teacher	-.01
Frequency of interactions with peer(s)	-.02
% of interactions with peers	-.04
Frequency of interactions with administrator	-.07
Frequency of interactions with other counterparty	-.06

Table H4

Correlations Between Time on Computer and Frequency or Percentage of Interaction Groupings

Grouping of interaction	Time on computer
one-on-one	.17*
% one-on-one	.27**
Small group	-.09
% small group	-.13
Large group	-.02
% large group	-.01
Whole group	-.20**
% whole group	-.24**

Table H5

Correlations Between Time on Computer and Frequency or Percentage of Different Interaction Groupings With Teacher

Grouping of interactions with teacher	Time on computer
One-on-one with teacher	.28**
% one-on-one with teacher	.30**
Small group with teacher	-.04
% small group with teacher	-.09

The number of times the student read aloud increased with computer use time as indicated by Table H6. The number of responses to the teacher's comments and the frequency of "other" types of exchange, such as random exclamations, fell with increased computer use.

Table H7 indicates that greater computer use time was associated with a smaller percentage of personal/social turns and a greater percentage of turns in which the student called for attention. There was no relationship between computer use time and the number or percentage of instructional, administrative or disciplinary turns.

While the overall number of instructional turns was not found to be related to computer use time, further investigation was made regarding instructional turns with the teacher and with peers. Results are shown in Table H8. Increased computer use time was associated with a greater number of instructional turns one-on-one with the teacher.

More time on the computer was associated with more procedural and clarification questions and fewer reasoning questions being asked or answered by the observed student as shown in Table H9. Other types of questions as well as the overall number of

Table H6

Correlations Between Time on Computer and Frequency or Percentage of Types of Verbal Exchange

Type of exchange	Time on computer
Student question	.00
% of turns that are student questions	-.05
Student-led discussion	-.03
Student presentation	.02
Response to teacher's question	-.09
Response to teacher's comment	-.20**
Part of teacher-led discussion	.11
Response to peer's question	.00
Response to peer's comment	-.01
Reading aloud	.18*
Other type of exchange	-.15*

Table H7

Correlations Between Time on Computer and Frequency or Percentage of Different Content Types of Turn

Content type	Time on Computer
Instructional	.07
% instructional	.18
Administrative	-.04
% administrative	-.05
Disciplinary	-.12
% disciplinary	-.13
Personal/Social	-.12
% personal/social	-.21**
Indecipherable	-.01
Calling attention	.09
% calling attention	.19**

Table H8

Correlations Between Time on Computer and Frequency of Instructional Turns

Instructional turns	Time on computer
With teacher	-.02
With teacher one-on-one	.28**
With teacher in a small group	.07
With peers	.08

Table H9

Correlations Between Time on Computer and Frequency of Question Types

Question type	Time on computer
Yes/no response required	-.04
Single correct factual answer	.01
Multiple possible correct factual answers	-.09
Opinion	.07
Reasoning	-.25**
Problem-solving with single correct answer	-.13
Procedural	.20**
Clarification	.15*
Total number of instructional questions	.05
Total number of all questions	-.03

questions and the number of instructional questions asked or answered by the observed student were not associated with computer use.

<u>Feedback</u>

Amount of time using computers was not associated with overall amount of verbal or written feedback received by the observed student from the teacher, peers or other parties as indicated in Table H10. The only significant association found between computer use and feedback was that students who used a computer for more time received less feedback directed at a large group of students than those who used a computer less.

Table H10

Correlations Between Time on Computer and Frequency of Feedback Received by Observed Student

Feedback type	Time on computer
Total verbal feedback	-.02
Verbal feedback from teacher	-.02
Verbal feedback from peer	.01
Verbal feedback from other counterparty	-.07
Individual verbal feedback received by observed student	.03
Verbal feedback received by observed student in a pair	.10
Verbal feedback received by observed student in a small group	-.07
Verbal feedback received by observed student in a large group	-.16*
Written feedback	.04

Activities and Assignments

Greater time using a computer was associated with fewer changes in activity during the observation period (r (191) = -.45, $p < .01$) and fewer changes in assignment to be worked on (r (191) = -.45, $p < .01$). Students spending more time using computers generally worked longer periods of time on a few activities rather than spending a few minutes each on several different activities. Greater computer use was also associated with more time on task (r (191) = .18, $p < .05$).

Table H11 indicates the relationships between computer use time and types of activity in the classroom. Greater computer use time was associated with less time involved in the following activities: listening to or watching the teacher; working on problems and exercises; participating in teacher-led discussion or question and answer sessions; conducting laboratory sessions or experiments as per instructions; being off-task. Greater computer use time was associated with more time involved in the following activities: conducting research on the Internet; working on a project; word processing.

Table H11

Correlations Between Time on Computer and Time Spent on Different Types of Classroom Activity

Type of activity	Time on computer
Listening to or watching the teacher	-.36**
Copying notes	-.08
Working on problems/exercises	-.23**
Reading assigned material	-.14
Viewing video/slides	-.12
Teacher-led discussion/question and answer session	-.40**
Devising problems/tasks	-.07
Open discussion	-.03
Conducting laboratory exercises/experiments	-.34**
Free experimenting	-.07
Peer tutoring	.06
Presenting	.09
Conducting research on the Internet	.46**
Working on a project	.38**
Word processing	.24**
Setting up/packing up	.02
Off-task	-.18*
Other activity	-.07

Greater computer use by students was associated with more time working independently and less time working as a whole group as indicated in Table H12.

Table H12

Correlations Between Time on Computer and Time Spent in Different Student Groupings for Classroom Activities

Student grouping	Time on computer
Independent	.49**
In pairs	.12
In small groups of 3-7	-.05
In large groups of 8 or more	-.07
Whole class	-.55**

More time spent using computers was associated with less time during which all students were working on the same activity (r (191) = -.70, $p < .01$) and more time during which the activity varied among students depending on interests (r (191) = .22, $p < .01$) or in some other way (r (191) = .63, $p < .01$). Usually "other" was noted when students were working at different paces so that some had moved on to a different assignment or when students working in groups allocated different tasks to each group member. It should be noted that while the observation instrument allowed for the recording of variation in activity depending on students' academic ability and also depending on learning styles, no instances of either were observed.

Amount of computer use was not associated with who gave the assignment to be worked on. Specifically there was no association between time on the computer and time spent on activities given by the teacher (r (191) = -.02, $p > .05$), time spent on activities selected by the student from a list of alternatives (r (191) = .13, $p > .05$) or time spent on activities devised by the student him or herself (r (191) = .08, $p > .05$).

Note that while the previously reported questionnaire data indicated that students using computers more often felt they had more choice in assignments worked on, the observation data provides a more precise picture of what this "choice" actually meant. It is not that students had more freedom to select the activity, but once an activity had been assigned, greater computer use was associated with more freedom to direct that activity according to the student's interests and/or to the student's pace of working.

Resource Use

More time on the computer was associated with a greater number of resources being used during class (r (191) = .36, $p < .01$). Additionally, students who used computers more were also more likely to select resources for use at their own initiative (r (191) = .54, $p < .01$) rather than being directed to use them by the teacher.

Time on the computer involved the use of desktop and laptop computers and computer-related content including on-line material and computer software. Software programs observed in use were: Grolier's Encyclopedia, Powerpoint, Netscape, Microsoft Word, Appleworks, Clarisworks, Student Writing Center, Hyperstudio and Internet Explorer.

Associations with other types of resources were also found. Table H13 illustrates the association between computer use time and the types of resources used in the classroom by the observed student for completing his or her assignments. Greater computer use was associated with greater use of the teacher and less use of the black (or white) board, worksheets, television or video and laboratory equipment. The observation instrument allowed for the recording of library use and use of outside experts but no instances of either were observed in the 191 classes observed.

Table H13

Correlations Between Time on Computer and Types of Resources Used

Type of resource	Time on computer
Teacher	.16*
Black/White board	-.41**
Peers	.13
Textbook	-.05
Worksheets	-.27**
Primary source material	-.07
Reference books	.06
Television/video	-.16*
Overhead projector	.09
Other teacher	-.09
Laboratory equipment	-.36**
Calculator	-.13
Other resource	-.10

Teacher Demographic Variables

Table H14 indicates associations between computer use time and teacher demographic variables. Students of female teachers used computers more than those of male teachers. Students of White teachers used computers less than students of other teachers and students of Latino teachers used computers more than students of other teachers. Note, however, that female teachers in the study were also more constructivist and many were Latino so that these three variables are closely interconnected.

Table H14

Correlations Between Time on Computer and Teacher Demographic Variables

Teacher variable	Time on computer
Gender	.32**
White	-.33**
Latino	.36**
African-American	.06
Other racial group	-.06

Note. The teacher demographic variables are all dummy-coded. For gender, female = 1. For race White = 1, non-White = 0 etc.

Time spent by observed students on the computer was not associated with the teacher's level of education ($r\,(191) = -.02, p > .05$), the number of years the teacher had been teaching ($r\,(191) = -.03, p > .05$) or the teacher's age ($r\,(191) = .04, p > .05$). Students of more constructivist teachers used computers more than those of more traditional teachers ($r\,(191) = .25, p < .01$).

Teachers' Computing Experience and Skill

Table H15 shows associations between computer use time and the teacher's computing experience and skill. Student use of computers was positively associated with the teacher's attitude towards computers, the amount of time the teacher used computers per week for any purpose, the number of hours of technology-related professional development the teacher had received during the school year, the teacher's technology skill score and the number of years the teacher had been using computer technology in the classroom. There was no association between student use of computers and whether or not the teacher had a computer at home.

Table H15

Correlations Between Time on Computer and Teacher's Computing Experience and Skill

Teacher variable	Time on computer
Teacher's attitude towards computers	.34**
Teacher's possession of a home computer	.03
Total number of hours per week spent on the computer	.38**
Number of hours of technology-related professional development	.38**
Teacher's technology skill	.28**
Number of years using computers in the classroom	.23**

Teaching Strategies

Table H16 illustrates associations between student computer use time and various teacher-reported teaching strategies. Positive associations were found between computer use and the frequencies of a number of teaching strategies: small group activities; project work; grouping of students by ability; assigning different activities based on academic abilities; student oral presentations; students reviewing or discussing the work of other students; allowing students a choice in activity based on interest; allowing students a choice among resources; students developing their own learning activities; giving individual verbal feedback to students on work and having students synthesize

Table H16

Correlations Between Observed Computer Use and Teacher-reported Teaching Strategies

Teaching strategy	Time on computer
Small group activities	.18*
Independent work	-.02
Project work	.43**
Worksheet use	-.12
Textbook use	-.16*
Peer tutoring	-.05
Teacher presentations	-.14
Grouping by ability	.21**
Assigning different activities based on ability	.27**
Student oral presentations	.28**
Students reviewing/discussing other students' work	.21**
Students given choice in activity based on interest	.45**
Students given choice in resources used	.22**
Students develop own learning activities	.19**
Individual verbal feedback given to students	.22**
Individual written feedback given to students	.02
Students synthesize information from a variety of sources	.32**
Activities to improve students' standardized test scores	.10

information from a variety of sources. More computer use was associated with less use of textbooks.

While some of these associations between observed computer use and teacher-reported teaching strategies are substantiated by the observation data, others are not. Students using computers were more often observed working independently rather than in small or large groups. Computer use was observed to be associated with project work. No instances of ability grouping or overt assignment of activities based on academic ability were actually observed. Students using computers were not observed receiving more feedback on their work from peers or the teacher but did have more opportunity to express their own interests in completing their assignments as well as having more choice in resources. Based on observations, there was no significant association between computer use and the frequency of student oral presentations.

Classroom Variables

Table H17 indicates associations between observed student computer use time and various classroom characteristics. As would be expected, when the science class was held in a computer laboratory (as opposed to the regular classroom or a science laboratory) students used computers more. Computer use was not related to whether classes were held in the morning or afternoon. The number of students physically present in the classroom during observations was not related to computer use. Computer use was greater when the classroom as a whole was working on projects. Computer use was lower when the classroom as a whole was engaged in laboratory work. Computer use was unrelated to the duration of the class. Computer use by the observed student and total number of students using a computer in the classroom were positively correlated.

Table H17

Correlations Between Time on Computer and Classroom Variables

Classroom variables	Time on computer
Class held in a regular science classroom	-.09
Class held in a computer laboratory	.25**
Class held in a science laboratory	-.11
Class held in the afternoon (as opposed to morning)	.02
Number of students present in the classroom	-.11
Class working on a project	.56**
Class working on a laboratory assignment	-.41**
Duration of class	.00
Number of students in the class using a computer	.65**

Students in regular track classrooms used computers less whereas those in bilingual classrooms and "other" classrooms (special education, electives) used them more as indicated in Table H18.

Table H18

Correlations Between Time on Computer and Type of Class

Class type	Time on computer
Regular track	-.28**
Accelerated/Honors	-.05
Bilingual	.30**
Other class type	.16*

Note. Class type categories were dummy coded.

Students studying Life Science used computers more than students studying Earth Science, Physical Science or another curriculum (r (191) = .16, p < .05) whereas students studying Physical Science used computers less (r (191) = -.25, p < .01). There was no association between computer use and Earth Science (r (191) = .00, p > .05) or between computer use and whether or not students were required to take a standardized science test during the school year (r (191) = .01, p > .05).

Table H19 illustrates associations between computer use and the availability of working hardware. Computer use related positively to hardware availability. Interestingly, availability of one kind of hardware was generally associated with availability of other kinds of hardware so that classrooms that had more PCs also had more Macs available (r (191) = .21, p < .01) and those that had more desktops also had more laptops (r (191) = .21, p < .01). However, desktops were more likely to be Macs (r (191) = .89, p < .01) and laptops were more likely to be PCs (r (191) = .90, p < .01). Clearly schools in this study did not show a tendency to select one type of hardware to the exclusion of others.

School Variables

There was no association between the total number of students in a school and how much time students spent using computers (r (191) = .10, p > .05). However, computer use was higher in schools with a greater number of teachers (r (191) = .18, p < .05) and in those with a smaller student/teacher ratio (r (191) = -.30, p < .01). Additionally, in schools with larger numbers of students in Grades 7 and 8, computer use time was higher as shown by Table H20.

Table H19

Correlations Between Time on Computer and Hardware Availability

Hardware availability in observed classroom	Time on computer
Number of working computers	.52**
Number of working Internet connections	.49**
Number of Macintosh computers	.34**
Number of PCs	.46**
Number of laptops	.45**
Number of desktops	.36**
Number of printers	.36**

Table H20

Correlations Between Numbers of Students in Each Grade Level and Computer Use Time

Grade level	Time on computer
Grade 6	-.06
Grade 7	.27**
Grade 8	.22**

Table H21 indicates associations between computer use and school-level student demographic data. Computer use was not associated with the percentages of boys or girls in the school or with the number of English Language Learners and Special Education students. In schools where higher percentages of students received free lunch, computer use was also higher. Computer use was positively associated with the percentage of

Table H21

Correlations Between Computer Use Time and School-level Student Demographics

Student body variable	Time on computer
% boys	-.12
% girls	.12
% eligible for free lunch	.18*
% English Language Learners	.10
% Special Education	.03
% African-American	-.11
% Hispanic	.31**
% White	-.17
% Asian or other	-.25**

Hispanic students in the school and negatively associated with the percentage of Asian or other students.

Computer use was not associated with performance on either the Grade 8 English Language Assessment (r (191) = .00, p > .05) or the Grade 8 Mathematics Test (r (191) = .10, p > .05). Computer use was higher in schools benefiting from more technology initiatives (r (191) = .46, p < .01) and in those that had a dedicated technology person in the school (r (191) = .16, p < .05). However, there was no association between computer use and participation in one specifically identified technology initiative, a Technology Innovation Challenge Grant (r (191) = -.04, p > .05).

Appendix I

OBSERVATION OUTCOME DATA

This appendix summarizes the data collected regarding the classroom environment, interactions and activities from the 191 student observation schedules. The sample size for all statistics is 191 unless otherwise stated. Italicized figures indicate percentages but other statistics are generally frequency counts or durations in minutes. Observations lasted 30 minutes each. "Skew" is used as an abbreviation for "skewness".

Verbal Interactions

For each student observed, the number of verbal interactions was counted. On average students participated in 28 interactions throughout the 30 minutes observed as indicated in Table I1. An interaction was defined as a series of turns exchanged by the observed student and one particular person or group of people. An interaction ended when the counterparty changed. In situations where the conversation continued with the same counterparty/ies, the interaction ended when there was a pause of more than a few seconds in the interchange, sometimes, but not always, accompanied by a change in topic. Sometimes a topic changed without any pause and this was considered a continuation of the first interaction.

Additionally the number of turns was recorded. The mean number of turns per student was 72 as indicated in Table I1. A turn was defined as a series of words or phrases spoken by one individual without interruption from another person. The number of turns per interaction was calculated as a measure of the complexity of the conversations occurring. The mean number of turns per interaction was 2.25 as shown in Table I1. The range was very wide for all three measures with some students saying

Table I1

Descriptive Statistics for Number of Verbal Interactions, Turns and Turns per Interaction

Counts	Min	Max	Mean	SD	Skewness	Kurtosis
Verbal interactions	0	95	28.46	18.99	0.78	0.20
Turns	0	264	71.64	54.34	0.99	0.68
Turns per interaction	0	22	2.25	1.68	8.30	93.26

nothing at all throughout the observation and others saying something almost nine times a minute.

The counterparty for each turn was recorded and the results are summarized in Table I2. In addition to raw counts, percentages of total turns were calculated for certain key variables. The table indicates that, on average, when students said something in class, almost 70% of the time it was directed at another student and almost 30% of the time it was directed at the teacher. Occasionally something was said to an administrator or someone else such as a teacher from another classroom.

For each turn it was noted whether the verbal exchange was with a single counterparty, a small group (2-6 other people), a large group (7 or more others but not the whole class) or the entire classroom. As shown in Table I3, when a student said something in the classroom, almost half the time (47.26% of turns) it was directed at one other person. Around 8% of turns were one-on-one with the teacher. Almost a third of the student comments were directed at a small group of students and almost 20% directed at the whole class. Very occasionally a large group was addressed but not the entire class.

Table I2

Descriptive Statistics for Number of Turns with Various Counterparties

Counterparty	Min	Max	Mean	SD	Skewness	Kurtosis
Teacher	0	76	15.17	15.17	1.75	3.61
% with teacher	*0.00*	*100.00*	*29.42*	*26.74*	*0.91*	*-0.11*
Peer(s)	0	258	56.16	50.93	1.07	0.78
% with peer(s)	*0.00*	*100.00*	*69.14*	*27.55*	*-0.89*	*-0.16*
Administrator	0	6	0.03	0.43	13.82	191
Other person	0	9	0.28	1.13	5.07	28.40

Turns were categorized as questions, part of a discussion, part of a presentation, responses to questions or comments, reading aloud or "other". "Other" might include calling attention or a random exclamation. Table I4 indicates that most turns were part of a student discussion. Student questions arose next most often (16.84% of all turns) followed by responses to the teacher's questions or to peer questions. Percentages are based on the total number of turns.

Turns were also categorized in terms of different content types: instructional, administrative, disciplinary, personal/social, calling attention or indecipherable. Table I5 shows that, on average, over half of all turns were instructional in content, almost a quarter personal/social and just over 15% administrative. A small percentage was disciplinary, calling attention or indecipherable. Percentages are based on the total number of turns.

Table I3

Descriptive Statistics for Turns Directed at Different Groupings in the Classroom

Grouping	Min	Max	Mean	SD	Skew	Kurtosis
One-on-one	0	165	29.39	34.54	1.87	3.86
% one-on-one	*0.00*	*100.00*	*47.26*	*35.56*	*0.04*	*-1.44*
One-on-one with teacher	0	45	3.19	6.54	3.19	12.69
% one-on-one with teacher	*0.00*	*93.75*	*8.10*	*17.30*	*2.76*	*7.90*
Small group	0	264	32.64	48.60	2.13	5.14
% small group	*0.00*	*100.00*	*31.72*	*33.94*	*0.83*	*-0.74*
Small group with teacher	0	66	3.92	9.71	4.45	23.15
% small group with teacher	*0.00*	*63.46*	*3.78*	*8.47*	*3.81*	*18.20*
Large group	0	74	0.59	6.04	10.92	124.41
% Large group	*0.00*	*84.09*	*0.69*	*7.00*	*10.67*	*118.19*
Whole group	0	77	9.01	12.65	2.45	7.53
% whole group	*0.00*	*100.00*	*19.29*	*25.81*	*1.55*	*1.44*

Instructional questions, both asked and answered by the observed student, were categorized as shown in Table I6. Percentages are based on total turns. Note that the last two rows address all types of questions (instructional, administrative, personal/social, disciplinary, other). Each student, on average, asked or answered almost 15 instructional questions throughout the 30 minutes observed. On average, almost a quarter of a student's turns constituted instructional questions or responses to instructional questions. Questions were most often procedural or required only a "yes" or "no" response.

Table I4

Descriptive Statistics for Turns Categorized by Type of Exchange

Type of turn	Min	Max	Mean	SD	Skew	Kurtosis
Student question	0	61	12.51	11.84	1.38	2.03
% student questions	*0.00*	*80.00*	*16.84*	*11.41*	*1.33*	*4.57*
Part of student discussion	0	209	37.82	37.37	1.40	2.30
Part of student presentation	0	6	0.04	0.46	12.21	155.85
Response to teacher question	0	29	5.94	6.35	1.47	1.80
Response to teacher comment	0	12	2.00	2.34	1.32	1.49
Part of teacher-led discussion	0	41	2.38	5.28	4.15	21.63
Response to peer's question	0	33	5.79	6.25	1.55	2.43
Response to peer's comment	0	13	1.06	1.61	3.16	16.41
Reading aloud	0	23	0.75	2.34	6.21	50.09
Other	0	23	1.75	2.99	3.31	16.18

Questions with multiple possible factual responses were rare as were those requiring an opinion or the clarification of an issue. Problem-solving questions with multiple possible answers never arose.

Table I5

Descriptive Statistics for Turns Categorized by Content Type

Content of turns	Min	Max	Mean	SD	Skew	Kurtosis
Instructional	0	190	38.45	34.46	1.56	2.80
% instructional	*0.00*	*100.00*	*54.32*	*23.97*	*-0.23*	*-0.54*
Instructional with teacher	0	71	10.76	11.94	1.99	5.40
Instr. w/teacher, one-on-one	0	30	2.31	5.10	2.87	8.77
Instr. w/teacher, small group	0	62	3.12	8.30	4.32	21.94
Instructional with peers	0	160	27.65	31.89	1.68	2.93
Disciplinary	0	22	1.23	2.72	4.24	24.77
% disciplinary	*0.00*	*15.38*	*1.37*	*2.61*	*2.44*	*6.56*
Administrative	0	48	10.08	9.86	1.43	1.85
% administrative	*0.00*	*88.89*	*15.20*	*13.15*	*2.02*	*7.56*
Personal/social	0	162	19.50	24.72	2.27	6.89
% personal/social	*0.00*	*96.43*	*23.58*	*19.95*	*1.13*	*1.41*
Indecipherable	0	8	0.77	1.36	2.69	9.52
Calling attention	0	17	1.61	2.26	2.63	11.73
% calling attention	*0.00*	*23.53*	*2.56*	*4.02*	*2.32*	*5.98*
Calling teacher's attention	0	17	0.95	1.85	4.39	30.50
% calling teacher's attention	*0.00*	*0.24*	*0.02*	*0.04*	*3.42*	*13.41*

Note. Instr. = Instructional; w/ = with.

Table I6

Counts of Types of Questions Asked and Answered by the Observed Student

Type of question (Q)	Min	Max	Mean	SD	Skew	Kurtosis
Yes/no	0	25	3.57	4.55	1.98	4.53
Factual – SCA	0	9	1.52	2.15	1.60	1.95
Factual - MCA	0	3	0.23	0.65	3.18	9.77
Opinion	0	4	0.10	0.48	6.49	47.80
Reasoning	0	13	1.10	2.22	2.78	8.33
Problem-solving – SCA	0	15	0.62	2.12	4.71	24.73
Problem-solving – MCA	0	0	0.00	0.00	N/A	N/A
Procedural	0	32	5.52	6.69	1.73	3.07
Clarification	0	7	0.70	1.31	2.34	5.62
*Other type of question	0	23	1.46	2.92	4.48	25.56
Undetermined category	0	1	0.03	0.16	5.98	34.15
Total # of instructional Q	0	73	14.84	12.64	1.74	4.33
% instructional questions	*0.00*	*88.89*	*24.64*	*16.54*	*1.08*	*1.25*
Total # of all Q asked/answered	0	91	24.23	17.82	1.18	1.73
% of all turns that were Q asked/answered	*0.00*	*100.00*	*38.20*	*17.87*	*0.81*	*1.42*

Note. SCA = single correct answer; MCA = multiple correct answers;

* Other questions might include requests to explain the meaning of a word, to make an observation about something being looked at or asking for feedback.

Feedback

Both verbal and written feedback received by the observed student on his or her work was recorded. It was noted from whom the feedback was received and whether it was directed at the student observed, the student plus a partner (a pair), a small group (3-7 students including the observed student) or a large group (8 or more students including the observed student). As shown in Table I7, on average students received just over 5 comments on their work during an observation. 80% of these comments were from the teacher with the remainder mostly from peers. About 65% of the comments were directed at the individual student and 17% at the whole group. Table I8 reflects that very few instances were observed of written feedback being provided to students.

Table I7

Counts of Verbal Feedback Comments Received by the Observed Student

Verbal feedback	Min	Max	Mean	SD	Skew	Kurtosis
Total number of comments received	0	24	5.32	5.01	1.43	2.31
From teacher	0	24	4.25	4.53	1.52	2.60
From peer	0	11	1.07	2.16	2.62	6.94
From other party	0	1	0.01	0.07	13.82	191
Directed at individual	0	20	3.47	3.74	1.48	2.40
Directed at pair	0	23	0.55	2.33	6.99	56.72
Directed at small group	0	10	0.39	1.29	4.51	23.24
Directed at large group	0	21	0.91	2.31	5.19	36.41

Table I8

Counts of Written Feedback Received by Observed Student

Written feedback	Min	Max	Mean	SD	Skew	Kurtosis
Total written feedback	0	1	0.05	0.22	4.05	14.57
From teacher	0	1	0.04	0.20	4.61	19.46
From peer	0	1	0.01	0.10	9.70	92.96
Directed at individual	0	1	0.05	0.21	4.31	16.74
Directed at pair	0	1	0.01	0.07	13.82	191.00
Directed at small group	0	0	0.00	0.00	N/A	N/A
Directed at large group	0	0	0.00	0.00	N/A	N/A

Activities/Assignments

During the observation the observer timed the student's various activities noting many different aspects: the total number of activities the student engaged in during the 30 minutes; the total number of assignments given by the teacher (activity differs from assignment in that any activity directed by the teacher is considered an assignment whereas an activity not directed by the teacher, such as being off-task, is not considered an assignment); the nature and duration of each activity; the grouping of students for assignments; the uniformity of assignments across students in the class; the degree of choice in assignments. Note that all times are given in minutes with 30 minutes being the maximum.

As indicated in Table I9, the number of both activities and assignments engaged in by students ranged from 1 to 12. The mean number of activities was slightly higher

Table I9

Number of Activities and Assignments Engaged in by the Observed Student

Activity measure	Min	Max	Mean	SD	Skew	Kurtosis
Total number of activities	1	12	3.41	2.12	1.04	1.40
Total number of assignments	1	12	3.06	1.96	1.19	2.13

than for assignments (3.41 vs. 3.06) reflecting instances where students engaged in an activity not directed by the teacher such as chatting with a peer about non-academic issues.

Table I10 shows the amount of time spent on different kinds of activities during class. On average the activities students spent most time on included: participating in a teacher-led discussion or question and answer session, conducting research on the Internet, conducting experiments as per instructions, listening to or watching the teacher and working on problems or exercises. No instances were observed of students engaging in free reading or writing, computer simulations or using science content software. Activities categorized as "other" might include noting down a homework assignment, collecting and handing in homework or writing up observations.

Students were most likely to be grouped independently for assignments (a mean of around 11 minutes) as shown in Table I11. The next most common grouping was whole class (a mean of almost 10 minutes) followed by grouping in clusters of 3-7 students (a mean of around 4 minutes). Less often students were in pairs and rarely in large groups of 8 or more students.

Table I10

Time Spent (Minutes) by the Observed Student on Different Types of Activities

Type of activity	Min	Max	Mean	SD	Skew	Kurtosis
Total time on task	7.5	30.0	28.9	3.1	-4.06	19.59
Listening to/watching the teacher	0.0	22.1	2.4	4.7	2.29	4.70
Copying material from board/overhead	0.0	16.3	0.4	1.9	5.84	36.16
Working on problems/exercises	0.0	30.0	2.4	5.7	2.70	7.43
Reading assigned material	0.0	16.7	0.3	1.5	7.93	76.96
Viewing videos/slides	0.0	26.0	0.4	2.7	8.11	68.03
Teacher-led discussion/Q/A session	0.0	30.0	5.9	9.0	1.40	0.69
Devising problems/tasks	0.0	10.5	0.1	0.8	13.82	191.00
Open discussion	0.0	5.7	0.0	0.5	10.94	124.91
Conducting expts. as per instructions	0.0	30.0	2.6	6.1	2.54	6.01
Experimenting freely	0.0	17.8	0.1	1.3	13.82	191.00
Peer tutoring	0.0	30.0	0.3	2.5	10.44	114.40
Presenting	0.0	27.6	0.7	3.4	5.75	34.85
Free reading	0.0	0.0	0.0	0.0	N/A	N/A
Free writing	0.0	0.0	0.0	0.0	N/A	N/A
Sims./science content software	0.0	0.0	0.0	0.0	N/A	N/A
Internet research	0.0	30.0	4.2	9.5	2.04	2.48
Word processing	0.0	30.0	1.2	5.5	4.49	18.78
Setting up/packing up	0.0	28.6	1.0	3.0	5.59	41.69
Other activity	0.0	26.6	1.4	3.9	4.21	20.09

Note. expts. = experiments; sims. = simulations.

Table I11

Time Spent (Minutes) by the Observed Student Working in Various Groupings

Grouping	Min	Max	Mean	SD	Skew	Kurtosis
Independently	0.0	30.0	11.3	12.3	0.48	-1.49
In a pair	0.0	30.0	3.2	8.1	2.64	5.65
In a small group (3-7)	0.0	30.0	4.3	8.9	1.95	2.39
In a large group (8+)	0.0	22.8	0.1	16.6	13.46	183.69
Whole class	0.0	30.0	9.9	10.7	0.64	-1.06

Over half the time on average (almost 16 minutes), students were all working on the same assignment as indicated by Table I12. When assignments did vary across students, the variation fell into the "other" category most often. This generally constituted situations where students were working at different rates so that one student might have progressed much more rapidly with an initial assignment and had already moved on to another or where a group of students working on an assignment allocated different tasks to each individual. Less often assignments varied according to students' interests. No situations were observed where the teacher overtly specified different activities for different groups of students based on their academic abilities or learning styles.

Table I12

Time Allocation (Minutes) by Variability of Assignment

Variability of assignment across class	Min	Max	Mean	SD	Skew	Kurtosis
Same for all students	0.0	30.0	15.9	13.2	-0.14	-1.81
Varies with academic abilities	0.0	0.0	0.0	0.0	N/A	N/A
Varies with students' interests	0.0	30.0	4.4	9.7	1.94	2.09
Varies with learning styles	0.0	0.0	0.0	0.0	N/A	N/A
Varies in other way	0.0	30.0	8.6	12.1	0.93	-0.94

Students spent most of their class time (a mean of almost 28 out of the 30 observed minutes) working on assignments mandated by the teacher as indicated by Table I13. Just under one minute on average was spent on assignments chosen from a list of alternatives. It was rare for a student to work on an activity he or she had devised him or herself and no student was observed working on an activity devised by another student.

Table I13

Time Allocation (Minutes) by Origin of Assignment

Origin of assignment	Min	Max	Mean	SD	Skew	Kurtosis
Given by teacher	0.0	30.0	27.7	5.7	-3.32	11.30
Student chose from list of alternatives	0.0	30.0	0.9	4.4	5.38	28.63
Devised by observed student	0.0	15.0	0.3	1.6	6.84	52.62
Devised by another student	0.0	0.0	0.0	0.0	N/A	N/A

Resources

The number of resources used by students for completing their assignments in class ranged from 2 to 10 with a mean of 5.02 as shown by Table I14. Most of the time the teacher directed students to a resource but, on average, 16.5% of the resources used were at the student's own initiative. 51% of the students observed used one or more resources at their own initiative.

Table I14

Resource Use by Observed Students

Resource use	Min	Max	Mean	SD	Skew	Kurtosis
Total number of resources used	2	10	5.02	1.53	0.74	0.35
Resources used at student's initiative	0	5	0.86	1.09	1.37	1.52
% of resources used at student's initiative	*0.00*	*100.00*	*16.51*	*20.42*	*1.23*	*1.18*

Table I15 shows the percentage of students observed who used the resources listed for completing their assignments in class. Peers and the teacher were the most commonly used resources followed by a black or white-board and computer software. "Other" resources included items such as a globe, a project poster-board, plants and manipulatives. No situations were observed in which the student used the library or outside experts as resources.

Table I15

Types of Resources Used by Observed Students for Completing Assignments in Class

Resource	% of observed students using this resource
Peers	96.3
Teacher	92.1
Black/White-board	53.9
Computer software (any type)	46.1
"Other" resource	41.4
Desktop computer	31.4
On-line material	25.1
Textbooks	23.6
Lab equipment	22.0
Worksheets	16.8
Netscape	15.2
Laptop computer	15.2
Internet Explorer	9.9
Microsoft Word	7.3
Clarisworks	6.3
Other teacher	5.8
Powerpoint	4.2
Appleworks	4.2
Hyperstudio	4.2
Overhead projector	4.2
TV/Video	3.1
Calculator	2.1
Reference books	1.6
Grolier's encyclopedia CD/ROM	1.0
Primary sources	0.5
Student Writing Center (software)	0.5
Library	0.0
Outside experts	0.0

Appendix J

MULTILEVEL REGRESSION MODELS INVESTIGATING THE RELATIONSHIP BETWEEN STUDENT-REPORTED FREQUENCY OF COMPUTER USE AND STUDENT-REPORTED INDICATORS OF INDIVIDUALIZED INSTRUCTION

The school, teacher/classroom and student questionnaire data was subjected to multilevel regression analysis using HLM version 5, a software program developed by Raudenbush, Bryk, Cheong and Congdon (2001), that employs hierarchical linear or non-linear modeling. While linear modeling is applied to normally distributed data, other models are available to allow analysis of frequency data and categorical outcomes.

Multilevel analysis is a methodology for the analysis of data with complex patterns of variability and, specifically, nested sources of variability (Snijders & Bosker, 1999). It accounts for the nested structure of the data whereby students who are in the same classroom cannot be considered totally independent as they are subject to some of the same factors such as the teacher's teaching philosophy, access to computers, teaching strategies and so forth. Because statistical tests of significance depend on the number of independent observations, the introduction of such intra-class correlation renders significance tests in traditional models too liberal (Kreft & De Leeuw, 1998). The result is that data analysis is more likely to produce significant results that may not be valid once this lack of independence is accounted for. In the case of the data collected in this study, treating the data as single level by disaggregating teacher level data in order to apply it to the higher number of student cases would introduce the possibility of finding falsely significant relationships (Hox, 1995).

The hierarchical linear model is an extension of the multiple linear regression model to a model that includes nested random coefficients (Snijders & Bosker, 1999). According to Raudenbush & Bryk (2002), hierarchical linear models are "more homologous with the basic phenomena under study" (p.5). Multilevel regression models allow for the partitioning of an outcome variable's variance into different levels, for example, within and between units (Heck & Thomas, 2000). In this case, it provides a means of partitioning the variability among students from variability among teachers/classrooms.

In multilevel modeling, separate first-level models are fitted for each group or context. For this study that means that each group of students taught by the same teacher is modeled separately. The same explanatory variables are applied to each set of students and the same outcome variable is investigated but the regression coefficients can vary from group to group. These first-level models are linked by a second-level model in which the regression coefficients of the student-level models are regressed on the teacher/classroom-level explanatory variables (Kreft & De Leeuw, 1998).

In comparison to a multiple linear regression analysis, the multilevel analysis is more rigorous and can be used to verify whether the relationships identified between specific independent and dependent variables at the various levels are robust despite the nested structure of the data.

In the multilevel models used to analyze data in this study, student variables from student questionnaires (or the student observations) made up the first level of data. Teacher/classroom and school variables made up the second level. These second level variables derived from teacher questionnaires, school data sheets and some items from the classroom observations. While some of the data has been modeled linearly assuming a normal distribution, in other cases different models were used given the non-linear nature of the data. Count data was analyzed assuming a Poisson distribution and categorical outcomes analyzed using an ordinal model.

School variables were included at the teacher/classroom level as only 20 schools were involved in the study. Such a small sample size is unlikely to provide enough variability in the school level data collected to merit analysis at a separate level. In particular, 5 of the schools were represented by only one teacher and 8 schools by only two teachers. If each school were represented by 3 or more teachers, schools could be added as a third level of analysis (although five or more teachers per school would be ideal). In practice, school level variables were rarely found to have a significant impact on the outcome variables under investigation in this study once the nested structure of the data was taken into account so that the final HLM analyses reported only include variables from the student and teacher/classroom levels.

(Note, however, that the three level model in the HLM version 5 software cannot cope with ordinal analysis so it would not be possible to investigate the ordinal outcome variables from the student questionnaire dataset using this software program. The new HLM version currently being beta-tested will allow for this analysis).

<u>Control Variables</u>

A number of variables were selected as particularly important to use as control variables in the analyses of whether computer use affects various indicators of individualized instruction. Many of these are teacher variables as the teacher is in control of setting the tone for the classroom in terms of both computer use and the instructional environment. The selection of control variables was based partly on factors found to be significant in previous studies of the classroom environment and partly on factors already found to be significantly correlated with frequency of computer use in this study. Clearly many other variables could be considered viable candidates to employ as controls. However, in the interests of parsimony and given limitations on the statistical models imposed by the study sample size, only the nine described below were included for multilevel analysis of the student questionnaire data.

Student's Grade Point Average (GPA): There are many studies indicating that students experience instruction differently depending on their achievement levels whether because of differences in resources available, differential treatment from the teacher or different curriculums. Additionally, the study by Schofield (1995) of computer-rich classrooms indicated that, compared with normal classroom situations, lower-achieving students received more attention from the teacher. Four achievement scores were available in this study: standardized reading; standardized mathematics; GPA and latest semester science score. GPA was selected for use as the control variable because it correlated more than the reading and math scores with frequency of computer use and had fewer missing data entries. While science scores showed a stronger correlation with frequency of computer use, this variable was not selected for control purposes because it is less representative of the student's overall achievement levels.

Teacher's gender: Gender was included because it was found to correlate with both frequency of student computer use and the amount of time students spent using a computer in the classroom. Additionally gender was correlated with many of the indicators of individualized instruction under study.

Teacher's ethnicity: This variable was included because it was found that ethnicity was significantly related to a number of the outcome variables being investigated in this study as well as computer use.

Teacher's philosophy: This study confirmed the finding of previous studies (e.g. Ravitz & Becker, 2000) that constructivist teachers tend to have students use computers more in the classroom compared with traditional teachers hence the importance of controlling for this factor. Teacher philosophy was also correlated with a number of the outcome variables under study.

Teacher's attitude towards computers: Teachers with more positive attitudes towards computers more often employ computers as part of classroom instruction according to this study and many previous studies.

Projects: The link between project work and computer use has been established in many instances. Difficulty arises in trying to determine whether it is the use of computers or the project method that was affecting the outcomes being monitored, hence the importance of including frequency of project work as a control variable.

Availability of working computers: Clearly one of the general constraints on computer use in the classroom is availability of working hardware and software in the classroom itself. This study confirmed that hardware availability was correlated positively with computer use. By controlling for computer availability it was possible to determine whether, holding availability constant, actual student computer use was associated with the outcome variables under study.

Type of class: In this study it was apparent that students in regular track science classrooms generally used computers less than those in accelerated/honors classrooms, bilingual classrooms or other classrooms hence the need to control for class type. Additionally, students in different types of classes are likely to experience different instructional strategies that in turn will impact the indicators of individualized instruction.

Class size: Class size was correlated with frequency of computer use and with some of the indicators of individualized instruction. In general, it is considered by many researchers to be a key determinant of the instructional environment.

A key question in this study was whether computer use in the science class was associated with indicators of individualized instruction above and beyond any effects of the student's GPA, the teacher's philosophy, teacher's gender and ethnicity, the teacher's attitude towards computers, amount of project work, availability of working computers, type of class and class size.

Multilevel Models for the Student Questionnaire Data

For the multilevel analysis of the student questionnaire data, three models were compared:

1) A random intercept only model which sought to establish only whether there was any significant difference among groups in the intercepts for the relevant outcome variable. This also provided a baseline variance that could be compared with the final model variance to establish how effectively the final model explained the variance among groups.

2) A basic model with fixed intercept and slopes, the equivalent of a traditional single level model, investigated the effect of only two student level variables on the outcomes: grade point average (GPA) and frequency of computer use (RSCICOMP). GPA was grand mean centered so that the intercepts became adjusted means for each

class. Frequency of computer use was the factor under investigation in this analysis with the aim of determining whether and how computer use in the classroom was associated with various indicators of individualized instruction. GPA was included so that differences in students' achievement levels could be controlled for given pre-existing evidence that this variable influences students' classroom experiences.

3) The final model introduced higher level (teacher/classroom) variables: teacher's philosophy score; teacher's attitude score towards computers; teacher's ethnicity; teacher's gender; teacher-reported amount of time per week spent by students on project work; number of working computers in the science classroom; type of class (regular/ bilingual/ accelerated or honors/ other); class size. These variables were added to investigate whether they were also associated with the outcomes and whether, once these factors were accounted for, GPA and/or frequency of computer use still had any predictive value with respect to the outcomes.

Technical Specifications for the HLM Models Used to Analyze the Student Questionnaire Data

The technical specifications for the HLM models are indicated in this section. The outcomes investigated were student-reported:

1) INDIVSCI: level of individual attention received in the science class compared with other classes at school;

2) INTERACT: level of peer interactions for academic purposes in the science class compared with other classes at school;

3) FEEDBACK: level of feedback received on work in the science class compared with other classes at school;

4) RCHOICAS: degree of choice in assignments worked on in the science class;

5) RSAMEWOR: extent to which assignments are uniform across students in the science class;

6) RRCHOICR: level of choice in resources used to complete assignments in the science class.

For all outcomes the original response categories were recoded into three possible response categories such as “more” / “same” / “less” or “a lot” / “some” / “not much”. Responses of “don’t know” or skipped responses were treated as missing data (see reference to this missing data in Appendix F). The three response categories were treated as ordinal. In specifying the HLM model, non-linear specifications were selected and an ordinal model with three categories entered.

1) Random intercept only model

Level 1 (Student level)

Outcome = $\beta_0 + \delta_{(2)}$ (THOLD2)

Level 2 (Class level)

$\beta_0 = \gamma_{00} + \mu_0$

β_0 is the intercept coefficient. In the ordinal model it is also the threshold between the first and second response categories. The last term in the level 1 equation, $\delta_{(2)}$ (THOLD2), is automatically generated by HLM when an ordinal analysis (as opposed to linear) is selected. It is the cut-off point or threshold between the second and third response categories. Technically, it is the threshold that separates the second and third cumulative logits. The level two intercept coefficient is γ_{00} and μ_0 is the level two random effect.

2) Basic model

Level 1 (Student level)

Outcome = $\beta_0 + \beta_1$ (GPA) + β_2 (RSCICOMP) + $\delta_{(2)}$ (THOLD2)

GPA is the student's latest grade point average. β_1 is the coefficient for the GPA predictor variable. RSCICOMP is the frequency of computer use in the science class as reported by the student. The three categories of response were: "never", "one to three times a month", "one or more times a week." β_2 is the coefficient for the RSCICOMP (frequency of computer use) variable.

Level 2 (Class level)

$\beta_0 = \gamma_{00}$

$\beta_1 = \gamma_{10}$

$\beta_2 = \gamma_{20}$

In this basic model both the intercept and the slopes were fixed. It is assumed that GPA and frequency of computer use had similar effects across all classes in the study. This is the equivalent of a traditional single level analysis as might be conducted using SPSS.

3) Final model

For the final model the first level remained the same:

Level 1 (Student level)

Outcome = $\beta_0 + \beta_1$ (GPA) + β_2 (RSCICOMP) + $\delta_{(2)}$ (THOLD2)

However, the intercept (β_0) was now permitted to vary with a number of higher level variables introduced to determine which ones significantly affected the intercept (i.e. which ones could explain the differences in the outcome caused by GPA and/or frequency of computer use across the different classes).

Level 2 (class level)

$\beta_0 = \gamma_{00} + \gamma_{01}(CONSTRUC) + \gamma_{02}(ATTCOMPU) + \gamma_{03}(TEACHETH) + \gamma_{04}(TEACHGEN) + \gamma_{05}(PROJECTS) + \gamma_{06}(COMPUTER) + \gamma_{07}(RCLASSTY) + \gamma_{08}(CLASSIZE) + \mu_0$

Explanation of variables:

CONSTRUC = Teacher's philosophy score;

ATTCOMPU = Score of teacher's attitude towards computers;

TEACHETH = Teacher's ethnicity. This was also tested with a series of dummy coded (0/1) variables for four major ethnic groups: WHITETEA = White/non-White; LATTEACH = Latino/non-Latino; AFAMTEAC = African-American/Non-African-American; OTHERTEA = Other/Non-other;

TEACHGEN = Teacher's gender;

PROJECTS = Frequency with which the teacher reports students engage in project work in science class;

COMPUTER = Number of working computers in the classroom in which the science class takes place;

RCLASSTY = Type of class. This was also tested with a series of dummy coded variables (0/1) for three different types of class: REGULAR = regular track/non-regular track; ACCEL = honors or accelerated track/non-honors or accelerated track; BILINGUAL = bilingual/non-bilingual.

CLASSIZE = Number of students in the science class.

$\beta_1 = \gamma_{10}$

$\beta_2 = \gamma_{20}$

The slopes of GPA (β_1) and frequency of computer use (β_2) were held constant because in initial analyses they were not found to vary significantly across classrooms/teachers, that is, while the actual outcomes varied among classrooms depending on GPA and/or frequency of computer use, these variables had similar rates of impact across classrooms. This means that a unit increase in student computer use and/or GPA in one classroom had a similar impact on the outcome variable as a unit increase in other classrooms, even though the starting level (as indicated by the intercept) varied.

Actual results for the HLM analyses are reported in Appendix K for the questionnaire data and Appendix M for the observation data.

Appendix K

MULTILEVEL ANALYSIS RESULTS FOR STUDENT-REPORTED INDICATORS OF INDIVIDUALIZED INSTRUCTION

In interpreting the multilevel regression analysis results, only the general direction of the relationships between independent and dependent variables is provided, for example, whether more frequent computer use predicts more or less peer interaction. One detailed numerical analysis is provided at the end of this Appendix for the individual attention outcome as an example of how to quantitatively interpret the variable coefficients. The same methodology can be applied to the other outcome variables.

For each outcome, the key predictor variable being investigated was the frequency of computer use. The other variables were included primarily as controls and while several were not significant predictors of any of the six outcomes once in the model (teacher's philosophy score, teacher's attitude towards computers, frequency of project work, number of computers available in the classroom and class size), they remained in the models because they could not be dropped without significantly affecting the results.

Note that for all cases where the final estimation of fixed effects is reported, this is for the unit-specific model rather than the population average model. Significance of statistical tests is indicated as follows in all tables: * $p < .05$; ** $p < .01$. Coefficients and standard errors are rounded to three decimals places. Each table compares the coefficients and standard errors (SE) for the three different regression models: random intercept only model (R.I. Only Model), fixed intercept and slope model (Fixed Effects Model) and two-level random intercept model (Final Model).

1) Outcome = level of individual attention received in science class compared with other classes at school (INDIVSCI). Coding: 1 = "less", 2 = "same", 3 = "more".

For the random intercept only model, the final estimation of fixed effects for the individual attention outcome variable (Table K1) indicates that the mean value of the intercept differs significantly from zero. The final estimation of variance components indicates a variance component of 0.46 (χ^2 (49) = 97.75, $p < .001$). It can be concluded that the intercepts are indeed significantly different for the different groups and that further analysis is warranted to determine the source of that variation, that is, what causes students in different classrooms to report differing levels of individual attention. The intra-class correlation (ICC), calculated as variance/ (variance + ($\pi^2/3$)) is .12 . This represents the fraction of total variability that is due to the teacher/classroom level or the correlation between two randomly drawn students in one randomly drawn classroom (Snidjers & Bosker 1999). Being above the .05 threshold level usually required to merit a random intercept model, this supports the need for multilevel analysis.

The least squares estimates of fixed effects, also shown in Table K1, indicate that, in the basic fixed effects model accounting only for student level variables, frequency of computer use does not significantly predict the level of individual attention but that students with lower GPAs report more individual attention. The intercept differs significantly from zero.

For the final model, the final estimation of fixed effects (Table K1) indicates that more computer use in the class significantly predicts more individual attention after controlling for the other factors included in the model. GPA still remained a significant predictor of individual attention with lower GPA students claiming more individual attention. Additionally, it was found that students of Latino teachers were more likely to report greater individual attention than students of other teachers (White, African-American or Other).

The final estimation of variance components indicates a variance component of 0.28 ($\chi^2(41) = 62.35, p < .05$). It can be concluded that the residual variance of β_0 is statistically different from zero confirming that the intercept coefficient should be modeled as random as is done in this analysis. The variance has, however, been reduced by the introduction of explanatory second level variables.

By comparing the variance in the intercept only model with that of the final model, the proportion of between-group variance explained by the second level variables (class variables) can be determined. Between-group variance explained by the second level variables is given by:

$$\frac{\text{Variance (intercept only model)} - \text{Variance (final model)}}{\text{Variance (intercept only model)}}$$

$$= \frac{0.45991 - 0.27540}{0.45991}$$

$$= 0.40.$$

This means that 40% of the between-group variance in levels of individual attention is explained by teacher's philosophy score, teacher's attitude towards computers, teacher's gender and ethnicity, frequency of project work in the class, class size, class type and number of computers available in the classroom.

Table K1

Regression Coefficients for Individual Attention Outcome

Effect	R.I. only	model	Fixed effects	model	Final	model
	df =	49/565†	*df* =	563	*df* =	41/555‡
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Intercept	-2.372**	0.179	-2.149**	0.160	-2.605*	1.241
Student's GPA			-0.020*	0.009	-0.022*	0.011
Student's computer use			0.186	0.111	0.353*	0.169
Teacher's philosophy					-0.007	0.021
T. attitude to computers					-0.036	0.022
Frequency of project work					0.011	0.174
Teacher's gender					0.440	0.284
Class size					0.027	0.027
Number of computers					-0.007	0.016
Bilingual class					-0.828	0.462
Latino teacher					1.359**	0.361
THOLD2	3.876**	0.172	3.765**	0.169	4.012**	0.184

Note. T. = teacher; R.I. = random intercept; † *df* for the R.I. Only Model are given for the intercept/THOLD2; ‡ *df* for the Final Model are given for classroom level variables/ student level variables.

2) Outcome = level of peer interactions for academic purposes in science class compared with other classes at school (INTERACT). Coding: 1 = "less", 2 = "same", 3 = "more".

For the random intercept only model, the final estimation of fixed effects (Table K2) indicates that the value of the intercept differs significantly from zero. The final estimation of variance components indicates a variance component of 0.49 (χ^2 (49) = 113.23, $p < .001$). It can be concluded that the intercepts are indeed significantly different for the different groups and that further analysis is warranted to determine the source of that variation, that is, what causes students in different classrooms to report differing levels of interaction. The calculated ICC of .13 represents the fraction of total variability that is due to the teacher/classroom level and indicates that a random intercept model is warranted.

In the basic, fixed effects model the least squares estimates (Table K2) indicate that students who use computers more frequently interact more with peers for academic purposes. GPA is not significantly related to interaction level.

In the final model for this outcome, one additional control variable was included: the student's grade level. This was added because it correlated strongly with interaction level and none of the other variables in the model significantly predict interactions (teacher's gender only becomes significant once grade level is introduced). The final estimation of fixed effects (Table K2) indicates that frequency of computer use no longer predicts interaction levels once other variables are taken into account. However, students in lower grades do interact significantly more with peers for academic purposes, as do students of male teachers.

The final estimation of variance components indicates a variance component of 0.23 ($\chi^2(41) = 61.08, p < .05$). It can be concluded that the residual variance of β_0 is statistically different from zero confirming that the intercept coefficient should be modeled as random as is done in this analysis. The variance has, however, been reduced by the introduction of explanatory second level variables.

The between-group variance explained by the second level variables is .54. This means that 54% of the between-group variance in levels of interaction is explained by

Table K2

Regression Coefficients for Peer Interaction Outcome

Effect	R.I. only	model	Fixed effects	model	Final	model
	df =	49/528†	*df* =	526	*df* =	41/517‡
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Intercept	-2.017**	0.172	-1.759**	0.147	-5.183**	1.683
Student's GPA			0.008	0.008	-0.005	0.010
Student's computer use			0.244*	0.101	0.203	0.155
Student's grade level					-0.443**	0.158
Teacher's philosophy score					0.019	0.020
T. attitude to computers					-0.022	0.020
Frequency of project work					0.245	0.161
Teacher's gender					-0.617*	0.254
Class size					-0.003	0.025
Number of computers					0.019	0.016
Type of class					0.096	0.155
Teacher's ethnicity					-0.229	0.126
THOLD2	2.733**	0.146	2.574**	0.138	2.809**	0.153

Note. T. = teacher; R.I. = random intercept; † *df* for the R.I. Only Model are given for the intercept/THOLD2; ‡ *df* for the Final Model are given for classroom level variables/ student level variables.

teacher's philosophy score, teacher's attitude towards computers, teacher's gender and ethnicity, frequency of project work in the class, class size, class type and number of computers available in the classroom.

3) Outcome = level of feedback received on work in science class compared with other classes at school (FEEDBACK). Coding: 1 = "less", 2 = "same", 3 = "more".

In the random intercept only model, the final estimation of fixed effects (Table K3) indicates that the value of the intercept differs significantly from zero. The final estimation of variance components indicates a variance component of 0.68 (χ^2 (49) = 139.85, $p < .001$). It can be concluded that the intercepts are indeed significantly different for the different groups and that further analysis is warranted to determine the source of that variation, that is, what causes students in different classrooms to report differing levels of feedback. The calculated ICC of .17 represents the fraction of total variability that is due to the teacher/classroom level and indicates that a random intercept model is merited.

In the basic, fixed effects model the least squares estimates (Table K3) indicate that students who use computers more frequently receive more feedback on their work. GPA is not significantly related to feedback level.

In the final model for this outcome variable, one additional variable was included: the frequency of textbook use in the classroom as reported by the teacher. This was added because it correlated strongly with feedback level reported by students and had a large impact on the model outcome. The final estimation of fixed effects (Table K3) indicated that frequency of computer use no longer predicted feedback levels once other variables were accounted for. However, several other variables were significantly related: greater textbook use predicted less feedback; students of female teachers received more feedback; students with lower GPAs received more feedback; students of teachers in the "Other" ethnicity category (primarily Caribbean American and Asian-American teachers)

Table K3

Regression Coefficients for Feedback Outcome

Effect	R.I. only	model	Fixed effects	model	Final	model
	df =	49/554†	*df* =	552	*df* =	40/543‡
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Intercept	-1.715**	0.171	-1.355**	0.129	-1.524	1.313
Student's GPA			-0.015	0.008	-0.024*	0.010
Student's computer use			0.284**	0.100	-0.010	0.155
Teacher's philosophy score					-0.007	0.021
T. attitude to computers					-0.00	0.02
Frequency of project work					0.205	0.173
Teacher's gender					0.671*	0.276
Class size					-0.003	0.027
Number of computers					0.015	0.016
Type of class					-0.074	0.162
Other/Non-other teacher					1.168**	0.396
Frequency of textbook use					-0.342**	0.107
THOLD2	2.867**	0.141	2.644**	0.129	2.946**	0.149

Note. T. = teacher; R.I. = random intercept; † *df* for the R.I. Only Model are given for the intercept/THOLD2; ‡ *df* for the Final Model are given for classroom level variables/ student level variables.

received more feedback. The final estimation of variance components indicates a variance component of 0.33 ($\chi^2(40) = 74.87, p < .01$). It can be concluded that the residual variance of β_0 is statistically different from zero confirming that the intercept coefficient should be modeled as random as is done in this analysis. The variance has, however, been reduced by the introduction of explanatory second level variables.

The between-group variance explained by the second level variables is .52. This means that 52% of the between-group variance in levels of feedback is explained by teacher's philosophy score, teacher's attitude towards computers, teacher's gender and ethnicity, frequency of project work in the class, class size, class type, number of computers available in the classroom and frequency of textbook use.

4) Outcome = degree of choice in assignments worked on in science class (RCHOICAS). Coding: 1 = "none/not much", 2 = "some", 3 = "quite a bit/a lot".

In the random intercept only model the final estimation of fixed effects (Table K4) indicates that the value of the intercept does not differ significantly from zero. Note, however, that this value represents the mean intercept value for the 50 different groups. Some individual group intercepts may be well above or below zero. The final estimation of variance components indicates that the variance component is 0.54 (χ^2 (49) =133.65, $p < .001$). It can be concluded that the intercepts are significantly different for the different groups and that further analysis is warranted to determine the source of that variation, that is, what causes students in different classrooms to report differing levels of choice in assignments. The calculated ICC of .14 represents the fraction of total variability that is due to the teacher/classroom level and indicates that a random intercept model is merited.

For the basic, fixed effects model, the least squares estimates of fixed effects (Table K4) indicate that students who used computers more frequently experienced greater choice in assignments worked on and students with lower GPAs also had more choice.

Table K4

Regression Coefficients for Choice in Assignments Outcome

Effect	R.I. only model		Fixed effects model		Final model	
	df = 49/624†		*df* = 622		*df* = 41/614‡	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Intercept	-0.155	0.137	0.246*	0.105	-0.442	1.210
Student's GPA			-0.028**	0.007	-0.025**	0.009
Student's computer use			0.502**	0.093	0.290*	0.141
Teacher's philosophy score					-0.017	0.021
T. attitude to computers					-0.018	0.021
Frequency of project work					0.139	0.171
Teacher's gender					0.152	0.273
Class size					-0.003	0.025
Number of computers					0.017	0.017
Bilingual class					0.770	0.385
Teacher's ethnicity					0.140	0.130
THOLD2	1.295**	0.089	1.240**	0.086	1.330**	0.092

Note. T. = teacher; R.I. = random intercept; † *df* for the R.I. Only Model are given for the intercept/THOLD2; ‡ *df* for the Final Model are given for classroom level variables/ student level variables.

In the final model, the final estimation of fixed effects (Table K4) indicates that more choice in assignments is predicted by more frequent computer use. Additionally, students with higher GPAs reported less choice in assignments. The final estimation of variance components indicates a variance component of 0.37 (χ^2 (41) = 87.24, $p < .001$). It can be concluded that the residual variance of β_0 is statistically different from zero confirming that the intercept coefficient should be modeled as random as is done in this analysis. The variance has, however, been reduced by the introduction of explanatory second level variables.

The between-group variance explained by the second level variables is .31. This means that 31% of the between-group variance in level of assignment choice is explained by teacher's philosophy score, teacher's attitude towards computers, teacher's gender and ethnicity, frequency of project work in the class, class size, class type and number of computers available in the classroom.

5) Outcome = level of variability in assignments across students in science class (RSAMEWOR). Coding 1 = "always the same", 2 = "usually the same", 3 "sometimes or never the same".

In the random intercept only model, the final estimation of fixed effects (Table K5) indicates that the value of the intercept does not differ significantly from zero. Note, however, that this value represents the mean intercept value for the 50 different groups. Some individual group intercepts may be well above or below zero. The final estimation of variance components indicates a variance component of 1.1 ($\chi^2(49) = 191.95$, $p <$ .001). It can be concluded that the intercepts are significantly different for the different groups and that further analysis is warranted to determine the source of that variation, that is, what causes students in different classrooms to report differing levels of variability in the work assigned across the class. The calculated ICC of .25 represents the fraction of total variability that is due to the teacher/classroom level and indicates that a random intercept model is warranted.

Table K5

Regression Coefficients for Variability in Assignments Outcome

Effect	R.I. only	model	Fixed effects	model	Final	model
	df =	49/665†	*df* =	663	*df* =	41/655‡
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Intercept	-.004	0.175	0.448**	0.103	0.429	1.324
Student's GPA			-0.002	0.007	0.006	0.010
Student's computer use			0.650**	0.092	0.505**	0.144
Teacher's philosophy score					0.017	0.023
T. attitude to computers					-0.011	0.023
Frequency of project work					0.333	0.189
Teacher's gender					-0.039	0.306
Class size					-0.038	0.027
Number of computers					0.004	0.019
Bilingual/Non-bilingual					1.441**	0.418
Teacher's ethnicity					0.052	0.144
THOLD2	2.060**	0.120	1.904**	0.113	2.123	0.126

Note. T. = teacher; R.I. = random intercept; † *df* for the R.I. Only Model are given for the intercept/THOLD2; ‡ *df* for the Final Model are given for classroom level variables/ student level variables.

In the basic, fixed effects model, the least squares estimates of fixed effects (Table K5) indicate that students who used computers more frequently claimed more variability in assignments across the classroom.

In the final model, the final estimation of fixed effects (Table K5) indicates that greater frequency of computer use predicted less uniformity (or more variability) in assignments. Students in bilingual classes reported more variability in work assigned across students compared with other classes (regular, honors/accelerated or other). The final estimation of variance components indicates a variance component of 0.52 (χ^2 (41) =105.80, $p < .001$). It can be concluded that the residual variance of β_0 is statistically different from zero confirming that the intercept coefficient should be modeled as random as is done in this analysis. The variance has, however, been reduced by the introduction of explanatory second level variables.

The between-group variance explained by the second level variables is .53. This means that 53% of the between-group variance in level of variability in assignments is explained by teacher's philosophy score, teacher's attitude towards computers, teacher's gender and ethnicity, frequency of project work in the class, class size, class type and number of computers available in the classroom.

6) Outcome = level of choice in resources used to complete assignments in science class (RRCHOICR). Coding: 1 = "none/not much", 2 = "some/quite a bit", 3 = "a lot".

In the random intercept only model the final estimation of fixed effects (Table K6) indicates that the value of the intercept differs significantly from zero. The final estimation of variance components indicates a variance component of 0.59 (χ^2 (49) = 155.24, $p < .001$). It can be concluded that the intercepts are significantly different for the different groups and that further analysis is warranted to determine the source of that variation, that is, what causes students in different classrooms to report differing levels of resource choice. The calculated ICC of .15 represents the fraction of total variability that

Table K6

Regression Coefficients for Choice in Resources Outcome

Effect	R.I. only	model	Fixed effects	model	Final	model
	df =	49/665†	*df* =	663	*df* =	41/655‡
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Intercept	-1.676**	0.157	-1.332**	0.117	-1.132	1.111
Student's GPA			0.026**	0.007	0.040**	0.009
Student's computer use			0.409**	0.091	0.310*	0.140
Teacher's philosophy score					-0.007	0.019
T. attitude to computers					0.030	0.020
Frequency of project work					-0.024	0.159
Teacher's gender					0.215	0.250
Class size					0.004	0.023
Number of computers					-0.018	0.016
Regular/non-regular class					0.027	0.266
White/Non-White teacher					-1.063**	0.264
THOLD2	2.381**	0.119	2.246**	0.112	2.462**	0.125

Note. T. = teacher; R.I. = random intercept; † *df* for the R.I. Only Model are given for the intercept/THOLD2; ‡ *df* for the Final Model are given for classroom level variables/ student level variables.

is due to the teacher/classroom level and indicates that a random intercept model is merited.

In the basic, fixed effects model, the least squares estimates of fixed effects (Table K6) indicate that students who use computers more frequently indicate more choice in resources used to complete assignments in the science class. Additionally, students with higher GPAs indicate more resource choice.

In the final model, the final estimation of fixed effects (Table K6) indicates that more computer use in the class significantly predicts more resource choice even after controlling for the other factors included in the model. GPA still remained a significant predictor of resource choice with higher GPA students claiming more resource choice. Additionally, it was found that students of White teachers were less likely to report a choice in resources than students of "Other" teachers (Latino, African-American or other). The final estimation of variance components indicates a variance component of 0.29 ($\chi^2(41) = 78.35$, $p < .01$). It can be concluded that the residual variance of β_0 is statistically different from zero confirming that the intercept coefficient should be modeled as random as is done in this analysis. The variance has, however, been reduced by the introduction of explanatory second level variables.

The between-group variance explained by the second level variables is .51. This means that 51% of the between-group variance in level of resource choice is explained by teacher's philosophy score, teacher's attitude towards computers, teacher's gender and ethnicity, frequency of project work in the class, class size, class type and number of computers available in classroom.

Detailed Numerical Interpretation of the Results for the Ordinal HLM Analysis of the Individual Attention Outcome

This interpretation is provided for the final model run for the individual attention outcome so that coefficient and threshold values used are taken from Table K1 (p. 246) although the coefficient signs in the table were reversed from the actual output signs to facilitate reader comprehension.

The three possible student responses to the question regarding amount of individual attention received from the teacher for academic purposes in science class compared with other classes were: “more” = 3; “same” = 2; “less” = 1.

The summary of the ordinal model specified in equation format is as follows:

Level 1 Model (Raudenbush, Bryk, Cheong & Congdon, 2001):

Prob [R = 1 | B] = P′ (1) = P (1)

Prob [R<= 2 | B] = P′ (2) = P (1) + P (2)

Prob [R <= 3 | B] = 1.0

Where

P (1) = Prob [Y (1) = 1 | B]

P (2) = Prob [Y (2) = 1 | B]

log [P′ (1) / (1 - P′ (1))] = B0 + B1*(GPA) + B2* (RSCICOMP)

log [P′ (2) /(1 - P′ (2))] = B0 + B1*(GPA) + B2* (RSCICOMP) + d (2)

Level 2 Model:

B0 = G00 + G01*(CONSTRUC) + G02*(ATTCOMPU) + G03*(LATTEACH) + G04*(TEACHGEN) +G05* (PROJECTS) + G06*(COMPUTER) + G07*(BILINGUAL) + G08*(CLASSSIZ) +U0

B1 = G10

B2 = G20

U0 is the level 2 random effect.

In general, the odds of a number x $= \dfrac{P(x)}{1 - P(x)}$

That is the probability of x divided by 1 minus the probability of x. For example, the odds of the response being “Less” is P′ (1) / (1 - P′ (1)) or the probability that a student selects the "Less" response category divided by the probability that the student does not select the "Less" response.

Y = outcome variable (e.g. level of individual attention)

B = the set of variables included in the model

P(1) = probability of student selecting a "Less" response given the chosen set of first and second level variables

P′ (2) = probability of student selecting a "Less" response plus the probability of student giving a "Same" response.

ln = natural log

e^x = the exponent of x (i.e. the inverse of the natural log)

Intercept and threshold coefficients: the intercept coefficient (-2.61) is the expected log-odds of a "Less"(coded 1) response relative to a "Same" (coded 2) or "More" (coded 3) response for a student, holding GPA and computer use constant with a random effect of zero. It is adjusted for the between group variability. From the results above:

$$-2.61 = \ln \frac{P(1)}{1 - P(1)}$$

$$e^{-2.61} = 0.07$$

This means that, holding other variables constant, the expected odds of a "Less" response is 0.07.

By adding the threshold value (4.01) to the intercept (-2.61) we obtain the log-odds of a "Less" (coded 1) or "Same" (coded 2) response relative to a "More" (coded 3) response, that is, the cumulative log-odds for categories 1 and 2:

$$-2.61 + 4.01 = \ln [P'(2)/(1 - P'(2))]$$

$1.4 = \ln [P'(2)/ (1 - P'(2))]$

$e^{1.4} = 4.06$ = odds of P′ (2)

This means that, holding other variables constant, the odds of a "Less" or "Same" response is 4.06.

In order to obtain the log-odds of a "More" response it would be necessary to recode the dependent variable for individual attention in the SPSS dataset so that a response of "More" had a value of 1 and the other two responses values of 2 and 3.

First level variable coefficients: GPA

P (1) "Less" response

For a single standard deviation increase in GPA, the log-odds of a student selecting "Less" rather than "Same" or "More" will increase by the coefficient 0.02 (holding other variables constant). That is, the odds of a "Less" response increases by $e^{0.02} = 1.02$ for a one standard deviation increase in GPA (from a descriptive statistics analysis in SPSS one standard deviation for GPA = 7.91 points).

P (2) "Same" response

The change in log-odds of a "Less" or "Same" response given a one standard deviation increase in GPA is 0.02 plus the threshold coefficient of 4.01:

$0.02 + 4.01 = 4.03$

$\Delta \ln [P'(2)/ (1 - P'(2))] = 4.03$

$e^{4.03} = [P'(2)/ (1 - P'(2))] = 56.26$

That is, the odds of a "Less" or "Same" response increases 56.26 times for a one standard deviation increase in GPA.

P (3) "More" response

In order to obtain the log-odds of a "More" response it would be necessary to recode the dependent variable for individual attention in the SPSS dataset so that a response of "More" had a value of 1 and the other two responses values of 2 and 3.

Frequency of computer use (RSCICOMP): the standard deviation of this categorical variable can be obtained from the SPSS descriptives function. The value is 0.837. As computer use increases one standard deviation, the log-odds of students selecting "Less" will decrease by the coefficient (-0.35) multiplied by the standard deviation (0.84):

Change in log odds of "Less" response = -0.35 * 0.84 = -0.294

Change in odds of "Less" response = $e^{-0.294}$ = 0.75

So the odds of getting a "Less" response when the frequency of computer use increases one standard deviation is 75% of what it was at mean computer use level.

The change in log-odds of a "Less" or "Same" response given a one standard deviation increase in frequency of computer use

= (-0.35 * 0.84) + 4.01 = 3.72

$e^{3.72} = 41.26$

So the odds of getting a "Less" or "Same" response given a one standard deviation increase in frequency of computer use increases 41.26 times from the odds at mean computer use level.

Second level coefficients: interpretation of numerical second level coefficients is relatively simple: for a one unit change in the variable, the intercept will increase or decrease by the coefficient amount. For example, for teacher's philosophy score, a unit increase in the score will raise the intercept from –2.61 to –2.60 (given a coefficient of

0.01). This new value can be used to determine a new set of probabilities for each response category. Clearly, in this case, the differences are so small as to be insignificant.

Categorical coefficients: in order to interpret any variables with multiple category responses the variables can either be recoded as dummy variables and interpreted as explained below or, if feasible, treated as continuous variables like the teacher philosophy score variable explained above.

Dummy-coded variables, for example, Latino/non-Latino teachers: the coefficient for Latino/non-Latino teachers is –1.36. This means that, holding other variables constant, the odds of a "Less" response being given by the student of a Latino teacher is $e^{-1.36}$ or .26 times the odds of a "Less" response for a student of a non-Latino teacher. In effect, students of Latino teachers are less likely to say they get less individual attention as compared with students of non-Latino teachers. In order to compare the odds of a "More" response among students of Latino/non-Latino teachers the data would need to be recoded with "More" coded as 1, "Same" still as 2 and "Less" as 3 and the analysis re-run. The resulting coefficient for Latino/non-Latino teacher could then be treated as before to achieve this objective.

Standard errors: the standard errors of the coefficients provide a measure of the range of values across groups. 68% of the actual group coefficients would be expected to fall within ± 1 standard error of the coefficient value shown and 95% within ± 2 standard errors of the value shown.

Appendix L

MULTILEVEL REGRESSION MODELS INVESTIGATING THE RELATIONSHIP BEWTEEN OBSERVED COMPUTER USE AND OBSERVED OUTCOME MEASURES SELECTED AS INDICATORS OF INDIVIDUALIZED INSTRUCTION

The 191 students observed were taught by 50 different teachers. Clearly students from the same classrooms share certain influences such as the teacher's characteristics and all classroom parameters. The observations cannot therefore be treated as completely independent data. Using a multilevel regression model with observed student variables in the first level and class variables in the second level recognizes the nested structure of the data and adjusts significance tests accordingly to avoid falsely significant results.

In contrast to the questionnaire data where the indicators of individualized instruction were categorical outcome variables, the observation data consisted of outcome variables most of which were counts, for example, of resources, assignments, interactions or minutes spent on various activities. These outcomes were investigated with HLM using a different non-linear model, the Poisson with a log link function (Raudenbush et al. 2001). As all students were observed for an equal period of time (30 minutes) the Poisson model with equal exposure was specified. Correction for overdispersion was also selected as the means and variances in the data were found not to be equal to a value of 1 (See Table 6, p.79). Some of the observation data were transformed into percentages, for example, the percentage of interactions that were one-on-one. These were treated as continuous data with the linear HLM model used for analysis.

A limited number of the outcomes from the observation data were selected for multilevel regression analysis. These items were specifically chosen as key indicators of individualized instruction in order to test whether the amount of time spent using a computer in class predicts the level of individualized instruction received by students. The chosen observation outcomes complement the outcomes investigated from the student questionnaire data.

The main independent variable used in the observation data analyses was the amount of time (in minutes) the student was observed using a computer during the 30 minute observation (TIMCOMP). A set of seven control variables was also included in the final models reported, some of which were identical to the controls used in the questionnaire data analyses: student's GPA, teacher's gender, teacher's ethnicity (limited here to White/non-White) and class type (limited here to Regular track/Non-regular track). The amount of time the student was observed engaging in project work replaced the teacher-reported variable regarding frequency of project work in the classroom. The student's gender and age were added because, despite the fact that these variables were not found to be correlated with computer use, they are not only theoretically important, but appeared in initial analyses to have a significant impact on the model results.

With a limited sample size of 191, the need for parsimonious models in analyzing the observation data was even greater than for the questionnaire data. A number of the teacher/class variables used in the questionnaire data regression analyses were not included in the final models for the observation outcomes because in initial analyses they were found to be insignificant predictors of all the outcomes under investigation. Chi-squared tests comparing the initial models with reduced models indicated no significant change in the models when the following variables were excluded: the teacher's philosophy score, the teacher's attitude towards computers, class size and the number of working computers available. In the observation regression models, two of the variables, student's age and whether or not the class was regular track, were not significant for any of the final model outcomes. However, they could not be dropped without a significant change in the deviance for one or more of the outcome analyses and were therefore retained.

The key question in this set of analyses was whether the amount of computer use in the science class predicted indicators of individualized instruction above and beyond any effects of the student's gender, age, GPA, amount of time spent on project work, teacher's gender, ethnicity and type of class.

Technical Specifications for HLM Analyses of Observation Data

Outcomes investigated in the observation data are:

1) VERBINT: the number of verbal interactions the observed student engaged in during the 30 minute observation;

2) TPERINT: the number of turns per interaction (this is a measure of the duration and complexity of the interactions);

3) PONEONE: the percentage of the student's turns that were one-on-one, that is, directed at a single counterparty;

4) SQPOOTEA: the square root of the percentage of the student's turns that were one-on-one with the teacher (a square root transformation was used to correct for a high skew and kurtosis in the original distribution);

5) SQPITEAC: the square root of the percentage of the student's turns that were one-on-one with the teacher and also instructional in content;

6) FEEDVERB: the number of comments directed at the observed student giving feedback on his or her work;

7) MSAME: the number of minutes the observed student spent working on assignments that were the same for all students in the class;

8) MGINDEP: the number of minutes the observed student spent working independently on assignments;

9) MGTEACHE: the number of minutes the student spent working on assignments that were given by the teacher rather than selected by the student from a list of alternatives or devised by the observed student him or herself;

10) TOTRESOU: the total number of resources used by the student to complete his or her assignments;

11) PSTUDINI: the percentage of resources used that were selected at the student's own initiative rather than at the teacher's direction;

12) ACTIVITI: the number of activities the observed student engaged in during the course of the observation.

The Poisson model used for the count data can be summarized in equation format as follows (Raudenbush et al., 2001):

Level 1 Model

$E(Y \mid B) = L$

$V(Y \mid B) = L$

$E(Y \mid B)$ = expected value (mean) of outcome variable Y given the variables in the model

V = variance of outcome variable

L is lambda or λ

log (L) = B0 + B1* (STUDENT VARIABLE 1) + B2 * (STUDENT VARIABLE 2)...

Level 2 Model

B0 = G00 + G01 (CLASS VARIABLE 1) + G02 (CLASS VARIABLE 2) +...+ U0

U0 is the level 2 random effect

Level-1 variance = 1/L

The variables measured as percentages were treated as continuous data with a regular linear model specified. The linear model can be summarized in equation format as follows (Raudenbush et al, 2001):

Level 1 Model

Y = B0 + B1* (STUDENT VARIABLE 1) + B2 * (STUDENT VARIABLE 2) + ...+ R

R is the level 1 random effect. It is assumed that R ~ N $(0, \sigma^2)$, that is, the random effect is distributed normally with a mean of zero and a variance of σ^2.

Level 2 Model

B0 = G00 + G01 (CLASS VARIABLE 1) + G02 (CLASS VARIABLE 2) +...+ U0

U0 is the level 2 random effect.

Similarly to the analysis of the six outcomes from the questionnaire data, three models are reported for each of the 12 outcomes selected from the observation data: a random intercept only model; a fixed intercept and slope model (the equivalent of a single level regression analysis) including five first level variables: student's age, gender, time spent on the computer, time spent on project work and GPA; a final two-level random intercept model with these same five student level variables and an additional three class level variables: teacher's gender, whether or not the teacher is White and whether or not the class is regular track. In the final models the intercept was allowed to vary with the second level (class) variables in order to determine which ones could explain differences in the outcomes across the 50 classrooms. The slopes of the first level variables (student's age, gender, GPA, amount of project work and amount of computer use) were held constant in the assumption that while the actual outcomes might vary across classrooms depending on these factors, they all had similar rates of impact across classrooms. This means that, for example, one unit increase in student computer use and/or GPA in one classroom is assumed to have a similar impact on the outcome variable as one unit increase in other classrooms, even though the starting level (as indicated by the intercept) varied.

The final models used in the analysis are therefore as follows:

Level 1 (student level)

$$Log (L) = \beta_0 + \beta_1 (STUDGEND) + \beta_2 (STUAGE) + \beta_3 (MPROJ) + \beta_4 (MTIMCOMP) + \beta_5 (GPA)$$

β_0 is the intercept coefficient.

STUGEND is the student's gender (male = 0, female = 1).

STUAGE is the student's age in years.

MPROJ is the number of minutes the observed student spent on project work during the 30 minute observation. This variable is grand-centered.

MTIMCOMP is the number of minutes the observed student spent using a computer during the 30 minute observation. This variable is grand-centered.

GPA is the student's latest grade point average. This variable is grand-centered.

$\beta_1 \ldots \beta_5$ are the coefficients for their respective predictor variables.

Level 2 (class level)

$\beta_0 = \gamma_{00} + \gamma_{01}(TGEND) + \gamma_{02}(REGULAR) + \gamma_{03}(WHITETEA) + \mu_0$

TGEND is the teacher's gender;

REGULAR is regular track (coded 1) /non-regular track (coded 0) classroom;

WHITETEA is White (coded 1)/non-White (coded 0) teacher.

$\beta_1 = \gamma_{10}$; $\beta_2 = \gamma_{20}$; $\beta_3 = \gamma_{30}$; $\beta_4 = \gamma_{40}$; $\beta_5 = \gamma_{50}$.

Appendix M

MULTILEVEL ANALYSIS RESULTS FOR OBSERVED INDICATORS OF INDIVIDUALIZED INSTRUCTION

For all cases where the final estimation of fixed effects is reported this is for the unit-specific model rather than the population average model. Significance of statistical tests is indicated as follows in all tables: * $p < .05$; ** $p < .01$. The sample size for this dataset was 191. Coefficients and standard errors are rounded to three decimal places. Each table compares the coefficients and standard errors (SE) for the three different regression models: the random intercept only model (R.I. Only Model) in which the degrees of freedom for the estimate of the intercept is 49, the fixed intercept and slope model (Fixed Effects Model) in which the degrees of freedom for the student level predictors and the intercept are 185, and two-level random intercept model (Final Model) in which the degrees of freedom are 182 for the student level predictors and 46 for the teacher/classroom level predictors and the intercept.

1) Outcome = the number of verbal interactions the observed student engaged in during the 30 minute observation (VERBINT). Poisson model specified.

For the random intercept only model (Table M1) it appears that the mean value of the intercept differs significantly from zero. The final estimation of variance components indicates a variance component of 0.10 ($\chi^2(49) = 105.72, p < .001$). It can be concluded that the intercepts are significantly different for the different groups and that further analysis is warranted to determine the source of that variation, that is, what causes students in different classrooms to interact more or less. The intra-class correlation (ICC)

Table M1

Regression Coefficients for Frequency of Verbal Interactions

Effect	R.I. only model		Fixed effects model		Final model	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Intercept	3.339**	0.062	4.042**	0.197	3.059**	0.761
Student's GPA			0.007**	0.002	0.004	0.007
Student's time on computer			-0.011**	0.001	-0.011*	0.005
Student's gender			0.111**	0.028	0.123	0.092
Student's age			-0.061**	0.016	-0.008	0.059
Student's time on projects			0.011**	0.001	0.013*	0.005
Teacher's gender					0.238	0.128
Regular class					0.120	0.135
White teacher					0.140	0.130

in the random intercept only model, calculated as level-2 variance/ (level-2 variance + level-1 variance) is, however, very low at .01 indicating little within-group homogeneity. The fixed effects model, which is appropriate for datasets with low ICCs, is compared with the final model which would be more appropriate given the significant level of variance found.

The fixed effects model (Table M1) suggests that more time on the computer and greater student age predict fewer verbal interactions whereas more time on project work, higher GPA and female student gender predict more interactions. In the final model (Table M1), with larger standard errors correcting for the clustering effect, GPA, gender and age are no longer significant predictors.

In the final model, the final estimation of fixed effects indicates that the mean value of the intercept differs significantly from zero. The value of 3.06 means that, holding all variables in the model constant, the expected number of verbal interactions per student during the 30 minute observation period is $e^{3.06}$ or 21.33. More computer use in the class significantly predicts fewer verbal interactions after controlling for the other factors included in the model. For a one standard deviation increase in the amount of time spent on the computer (14 minutes), the mean number of verbal interactions will decrease by $e^{-0.01}$ or 0.99 times, holding all other variables constant. More time spent on project work predicts more frequent verbal interactions. For a one standard deviation increase in the amount of time spent working on a project (10.8 minutes), the mean number of verbal interactions will increase by $e^{0.013}$ or 1.01 times, holding all other variables constant.

In the final model, the final estimation of variance components indicates a variance component of 0.08 ($\chi^2(46) = 89.61, p < .001$). It can be concluded that the residual variance of β_0 is statistically different from zero. This confirms that the intercept coefficient should be modeled as random as is done in this analysis to account for variation in the intercept value across the 50 classrooms. However, only 20% of the between-group variance in frequency of verbal interactions has been explained by the teacher's gender and ethnicity and the type of class. It must be concluded that this model is not an ideal fit and that there may be better second-level predictors of this outcome.

2) Outcome = the number of turns per interaction (TPERINT is a measure of the duration and complexity of the interactions). Poisson model specified.

For the random intercept only model (Table M2) it appears that the mean value of the intercept differs significantly from zero. The final estimation of variance components indicates a variance component of 0.05 ($\chi^2(49) = 116.69, p < .001$). It can be concluded that the intercepts are significantly different for the different groups and that further analysis is warranted to determine the source of that variation, that is, what causes students in different classrooms to have more or less turns per interaction. The intra-class correlation (ICC) in the random intercept only model is .09 indicating that a random intercept model is merited.

The fixed effects model (Table M2) suggests that only more time on project work predicts more turns per interaction. In the final model, several of the variables are found to be significant predictors. More computer use in the class predicts more turns per interaction after controlling for the other factors included in the model. More time spent on project work also predicts more turns per interaction. Students with higher GPAs have fewer turns per interaction. Students of White teachers have more turns per interaction than students of non-White teachers.

In the final model, the final estimation of fixed effects (Table M2) indicates that the mean value of the intercept does not differ significantly from zero. The numerical values of the coefficients can be interpreted as follows: the intercept value of 0.57 means that, holding all variables in the model constant, the expected number of turns per verbal interaction is $e^{0.57}$ or 1.77. For a one standard deviation increase in the amount of time spent on the computer (14 minutes), the mean number of turns per interaction will

Table M2

Regression Coefficients for Turns Per Interaction

Effect	R.I. only model		Fixed effects model		Final model	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Intercept	0.882**	0.048	0.650	0.672	0.569	0.544
Student's GPA			-0.007	0.006	-0.012*	0.005
Student's time on computer			0.003	0.004	0.007*	0.003
Student's gender			0.112	0.095	0.104	0.068
Student's age			0.016	0.053	0.009	0.042
Student's time on projects			0.013**	0.004	0.011**	0.004
Teacher's gender					-0.070	0.089
Regular class					0.180	0.092
White teacher					0.183*	0.089

increase by $e^{0.01}$ or 1.01 times, holding all other variables constant. For a one standard deviation increase in the amount of time spent working on a project (10.8 minutes), the mean number of turns per interaction will also increase by $e^{0.01}$ or 1.01 times, holding all other variables constant. For a one standard deviation increase in GPA (7.93 points), the mean number of turns per interaction decreases by $e^{-0.01}$ or 0.99 times, holding all other variables constant. For students of White teachers the mean number of turns per interaction is $e^{0.18}$ or 1.2 times greater than the mean for students of non-White teachers, holding all other variables constant.

In the final model, the final estimation of variance components indicates a variance component of 0.03 (χ^2 (46) = 68.06, $p < .05$). It can be concluded that the residual variance of β_0 is statistically different from zero confirming that the intercept coefficient should be modeled as random as is done in this analysis. Forty-eight percent of the between-group variance in turns per interaction has been explained by the teacher's gender and ethnicity and the type of class.

3) Outcome = the percentage of the student's turns that were one-on-one, that is, directed at a single counterparty (PONEONE). Linear model specified.

For the random intercept only model (Table M3) it appears that the mean value of the intercept differs significantly from zero. The final estimation of variance components indicates a variance component of 439.63 ($\chi^2(49) = 153.60$, $p < .001$). It can be concluded that the intercepts are significantly different for the different groups and that further analysis is warranted to determine the source of that variation, that is, what causes students in different classrooms to have more or less one-on-one turns. The intra-class correlation (ICC) in the random intercept only model is .35 indicating that a random intercept model is warranted.

The fixed effects model (Table M3) suggests that only more time on the computer predicts a greater percentage of turns that are one-on-one. This finding is reiterated in the final model (Table M3).

In the final model, the final estimation of fixed effects indicates that the adjusted mean value of the intercept does not differ significantly from zero (adjusted for the second level independent variables included in the model). More computer use in the class significantly predicts a greater percentage of one-on-one verbal interactions after controlling for the other factors included in the model. For a one standard deviation

Table M3

Regression Coefficients for Percentage of Verbal Interactions that are One-on-one

Effect	R.I. only model		Fixed effects model		Final model	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Intercept	45.240**	3.662	8.500	35.721	5.567	40.730
Student's GPA			-0.590	.344	-0.368	0.369
Student's time on computer			0.619**	0.193	0.735**	0.260
Student's gender			2.823	5.102	2.909	4.660
Student's age			2.976	2.834	3.582	3.133
Student's time on projects			0.196	0.252	-0.162	0.281
Teacher's gender					-1.422	7.625
Regular class					-11.221	8.044
White teacher					5.953	7.812

increase in the amount of time spent on the computer (14 minutes), the percentage of one-on-one interactions increases by 0.74%.

The final estimation of variance components in the final model indicates a variance component of 416.44 (χ^2 (46) =134.63, $p < .001$). It can be concluded that the residual variance of β_0 is statistically different from zero confirming that the intercept coefficient should be modeled as random as is done in this analysis. However, only 5% of the between-group variance in the percentage of turns that are one-on-one has been explained by the teacher's gender and ethnicity and the type of class indicating that there may be better second level predictors for this outcome.

4) Outcome = the square root of the percentage of the student's turns that were one-on-one with the teacher (SQPOOTEA). Linear model specified.

For the random intercept only model it appears that the mean value of the intercept (Table M4) differs significantly from zero. The final estimation of variance components indicates a variance component of 1.20 (χ^2 (49) = 97.38, $p < .001$). It can be concluded that the intercepts are significantly different for the different classes and that further analysis is warranted to determine the source of that variation, that is, what causes students in different classrooms to have more or less one-on-one turns with the teacher. The ICC in the random intercept only model is .18 indicating that a random intercept model is merited.

Table M4

Regression Coefficients for Square Root of Percentage of Verbal Interactions that are One-on-one With the Teacher

Effect	R.I. only model		Fixed effects model		Final model	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Intercept	1.411**	0.223	-0.586	2.434	-0.854	2.766
Student's GPA			-0.019	0.023	-0.009	0.026
Student's time on computer			0.056**	0.013	0.055**	0.017
Student's gender			0.048	0.348	-0.022	0.337
Student's age			0.165	0.193	0.189	0.214
Student's time on projects			-0.018	0.017	-0.043*	0.019
Teacher's gender					0.506	0.474
Regular class					-0.438	0.496
White teacher					-0.120	0.486

The fixed effects model (Table M4) suggests that more time on the computer predicts a greater percentage of turns that are one-on-one with the teacher. The final model (Table M4) also indicates that more computer use in the class significantly predicts a greater percentage of one-on-one verbal interactions with the teacher after controlling for the other factors included in the model. Additionally, the final model indicates that more time spent on project work predicts a smaller percentage of one-on-one interactions with the teacher after controlling for other factors included in the model.

From the final model, the final estimation of variance components indicates a variance component of 1.21(χ^2(46) = 91.36, p < .001). It can be concluded that the residual variance of β_0 is statistically different from zero confirming that the intercept coefficient should be modeled as random as is done in this analysis. However, given that the final model variance is actually larger than that for the random intercept only model, it must be concluded that the teacher's gender and ethnicity and the type of class are not good second-level predictors for this outcome.

5) Outcome = the square root of the percentage of the student's turns that were one-on-one with the teacher and also instructional in content (SQPITEAC). Linear model specified.

For the random intercept only model it appears that the mean value of the intercept (Table M5) differs significantly from zero. The final estimation of variance components indicates a variance component of 0.10 (χ^2(49) = 106.85, p < .001). It can be concluded that the intercepts are significantly different for the different classes and that further analysis is warranted to determine the source of that variation, that is, what causes

Table M5

Regression Coefficients for Square Root of Percentage of Verbal Interactions that are One-on-one With the Teacher and Also Instructional

Effect	R.I. only	model	Fixed effects	model	Final	model
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Intercept	0.107**	0.020	-0.127	0.212	-0.109	0.242
Student's GPA			-0.001	0.002	-0.000	0.002
Student's time on computer			0.005**	0.001	0.005**	0.002
Student's gender			0.025	0.030	0.021	0.029
Student's age			0.018	0.017	0.018	0.019
Student's time on projects			-0.001	0.002	-0.004*	0.002
Teacher's gender					0.024	0.041
Regular class					-0.040	0.043
White teacher					-0.015	0.042

students in different classrooms to have more or less one-on-one turns with the teacher for instructional purposes. The ICC in the random intercept only model is .23 indicating that a random intercept model is merited.

The fixed effects model (Table M5) suggests that more time on the computer predicts a greater percentage of turns that are one-on-one with the teacher for instructional purposes. The final model (Table M5) also indicates that more computer use in the class significantly predicts a greater percentage of one-on-one turns for instructional purposes with the teacher after controlling for the other factors included in the model. Additionally, the final model indicates that more time spent on project work predicts a smaller percentage of one-on-one turns with the teacher for instructional purposes after controlling for other factors included in the model.

The final estimation of variance components indicates a variance component of 0.009 (χ^2 (46) = 91.46, p < .001). It can be concluded that the residual variance of β_0 is statistically different from zero confirming that the intercept coefficient should be modeled as random as is done in this analysis. However, only 13% of the between-group variance in the percentage of turns that are one-one-one with the teacher for instructional purposes has been explained by the teacher's gender and ethnicity and the type of class indicating that there may be better second level predictors for this outcome.

6) Outcome = the number of comments directed at the observed student giving feedback on his or her work (FEEDVERB). Poisson model specified.

For the random intercept only model it appears that the mean value of the intercept (Table M6) differs significantly from zero. The final estimation of variance components indicates a variance component of 0.06 (χ^2 (49) = 61.79, p >.05). It can be concluded that the intercepts are not significantly different for the different classes and that a single level regression analysis with fixed intercepts and slopes may be sufficient to investigate predictors of feedback levels. The ICC in the random intercept only model is very low at .01 lending further support to this conclusion.

The fixed effects model (Table M6) suggests that more time on the computer does not predict feedback levels. However, the expected number of feedback comments received by female students, holding other variables in the model constant, is greater than the expected number for male students. Additionally, a higher GPA score predicts higher levels of feedback. The final, multilevel model, also included in Table M6, supports the

Table M6

Regression Coefficients for Feedback Received by Observed Student

Effect	R.I. only model		Fixed effects model		Final model	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Intercept	1.670**	0.073	1.601**	0.458	1.471	1.063
Student's GPA			0.013**	0.004	0.007	0.010
Student's time on computer			-0.004	0.002	-0.003	0.006
Student's gender			0.276**	0.066	0.318*	0.139
Student's age			-0.007	0.036	0.006	0.083
Student's time on projects			0.002	0.003	0.004	0.007
Teacher's gender					-0.078	0.167
Regular class					-0.050	0.172
White teacher					0.039	0.171

findings regarding student gender and computer use but does not support the finding regarding GPA.

In the final multilevel model, the final estimation of variance components indicates a variance component of 0.08 (χ^2 (46) = 60.63, p = .07). It can again be concluded that the level of the intercept does not vary a great deal among the 50 classrooms. Furthermore, given that this variance level is higher than that for the random intercept only model, the second level predictors in this model are not good predictors for the feedback outcome.

7) Outcome = the number of minutes the observed student spent working on assignments that were the same for all students in the class (MSAME). Poisson model specified.

For the random intercept only model it appears that the mean value of the intercept (Table M7) differs significantly from zero. The final estimation of variance components indicates a variance component of 0.84 ($\chi^2(49) = 323.55$, $p < .001$). It can be concluded that the intercepts are significantly different for the different classes and that further analysis is warranted to determine the source of that variation, that is, what causes students in different classrooms to spend more or less time working on the same assignment as other students in the classroom. The ICC in the random intercept only model is .13 indicating that a random intercept model is merited.

The fixed effects model (Table M7) indicates that more time on the computer and more time spent working on projects predicts less uniformity in assignments, that is, students spend less time working on the same assignment as all other students in the classroom. Additionally, younger students spend less time working on the same assignments as other students in the classroom. The final multilevel model (Table M7) also indicates that more computer use in the class and more time working on projects significantly predicts less time with all students working on the same assignment after controlling for the other factors included in the model. However, the predictive value of student's age disappears.

From the multilevel model, for a one standard deviation increase in the amount of time spent on the computer (14 minutes), the mean number of minutes spent working on the same assignment will decrease by $e^{-0.04}$ or 0.96 times, holding all other variables constant. For a one standard deviation increase in the amount of time spent working on a

Table M7

Regression Coefficients for Amount of Time Assignment was the Same for All Students

Effect	R.I. only model		Fixed effects model		Final model	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Intercept	2.664**	0.139	3.277**	0.261	3.584**	0.824
Student's GPA			0.003	0.002	0.000	0.008
Student's time on computer			-0.043**	0.002	-0.041**	0.006
Student's gender			-0.034	0.037	-0.041	0.110
Student's age			-0.066**	0.021	-0.086	0.063
Student's time on projects			-0.049**	0.004	-0.048**	0.011
Teacher's gender					-0.141	0.111
Regular class					-0.026	0.126
White teacher					0.091	0.117

project (10.8 minutes), the mean number of minutes spent working on the same assignment will decrease by $e^{-0.05}$ or 0.95 times, holding all other variables constant.

In the multilevel model, the final estimation of variance components indicates a variance component of 0.00013 (χ^2 (46) = 59.13, p = .09). It can be concluded that the level of the intercept no longer varies much among the 50 classrooms. The initial between-group variance that existed has been almost entirely (99.9%) explained by the teacher's gender and ethnicity and the class type.

8) Outcome = the number of minutes the observed student spent working independently on assignments (MGINDEP). Poisson model specified.

For the random intercept only model it appears that the mean value of the intercept (Table M8) differs significantly from zero. The final estimation of variance

Table M8

Regression Coefficients for Amount of Time the Observed Student Spent Working Independently

Effect	R.I. only model		Fixed effects model		Final model	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Intercept	1.969**	0.157	3.523**	0.317	4.271**	1.184
Student's GPA			-0.031**	0.003	-0.002	0.010
Student's time on computer			0.042**	0.002	0.035**	0.008
Student's gender			-0.001	0.045	-0.182	0.126
Student's age			-0.101**	0.025	-0.152	0.090
Student's time on projects			-0.001	0.002	-0.015*	0.007
Teacher's gender					0.209	0.311
Regular class					-0.311	0.326
White teacher					-0.428	0.321

components indicates a variance component of 0.92 ($\chi^2(49) = 420.93$, $p < .001$). It can be concluded that the intercepts are significantly different for the different classes and that further analysis is warranted to determine the source of that variation, that is, what causes students in different classrooms to spend more or less time working independently. The ICC in the random intercept only model is .12 indicating that a random intercept model is merited.

The fixed effects model (Table M8) indicates that more time spent on the computer predicts more time working independently. Additionally younger students and those with lower GPAs spend less time working independently. The final, multilevel model (Table M8) gives some different results. It indicates that more computer use in the class significantly predicts more time working independently, controlling for the other factors included in the model. Additionally, more time spent on project work predicts less time working independently. The findings regarding student's GPA and age are not supported in this model.

From the final model, for a one standard deviation increase in the amount of time spent on the computer (14 minutes), the mean amount of time spent working independently will increase by $e^{0.04}$ or 1.04 times, holding all other variables constant. For a one standard deviation increase in the amount of time spent working on a project (10.8 minutes), the expected amount of time spent working independently will decrease by $e^{-0.02}$ or 0.98 times, holding all other variables constant.

In the multilevel model, the final estimation of variance components indicates a variance component of 0.76 (χ^2 (46) = 243.06, $p < 0.001$). It can be concluded that the residual variance of β_0 is statistically different from zero. This confirms that the intercept coefficient should be modeled as random as is done in this analysis to account for variation in the intercept value across the 50 classrooms. However, only 17% of the between-group variance has been explained by the teacher's gender and ethnicity and the class type.

9) Outcome = the number of minutes the student spent working on assignments that were given by the teacher rather than selected by the student from a list of alternatives or devised by the observed student him or herself (MGTEACHE). Poisson model specified.

For the random intercept only model it appears that the mean value of the intercept (Table M9) differs significantly from zero. The final estimation of variance components indicates a variance component of 0.00 (χ^2 (49) = 45.97, $p > .50$). It can be

Table M9

Regression Coefficients for Amount of Time Spent on Assignments Given by the Teacher

Effect	R.I. only model		Fixed effects model		Final model	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Intercept	3.323**	0.015	3.119**	0.199	3.074**	0.226
Student's GPA			0.002	0.002	0.002	0.002
Student's time on computer			-0.000	0.001	0.000	0.001
Student's gender			-0.045	0.028	-0.056	0.032
Student's age			0.018	0.016	0.020	0.018
Student's time on projects			-0.000	0.001	-0.001	0.002
Teacher's gender					-0.014	0.034
Regular class					0.062	0.034
White teacher					0.001	0.035

concluded that the intercepts are not significantly different for the different classes and that a single level regression analysis with fixed intercepts and slopes is sufficient to investigate predictors of the amount of time spent on assignments given by the teacher. The ICC in the random intercept only model is also zero supporting this conclusion.

For both the fixed effect model and the multilevel model (included for comparison in Table M9), neither computer use in the class nor any of the other variables in the models predict the amount of time spent on assignments given by the teacher. This reflects the fact that in the vast majority of classes observed, regardless of the type of activity engaged in, it was the teacher who assigned the activity even if students were allowed flexibility in the details of execution.

10) Outcome = the total number of resources used by the student to complete his or her assignments (TOTRESOU). Poisson model specified.

For the random intercept only model it appears that the mean value of the intercept (Table M10) differs significantly from zero. The final estimation of variance components indicates a variance component of 0.04 (χ^2 (49) = 177.93, $p < .001$). It can be concluded that the intercepts are significantly different for the different classes and that further analysis is warranted to determine the source of that variation, that is, what causes students in different classrooms to use more or less resources. The ICC in the random intercept only model is .11 indicating that a random intercept model is merited.

The fixed effects model (Table M10) indicates that more time on the computer predicts a greater number of resources used by students for completing assignments. The final multilevel model (Table M10) confirms that more computer use in the class significantly predicts a greater number of resources used, controlling for the other factors included in the model. For a one standard deviation increase in the amount of time spent on the computer (14 minutes), the mean number of resources used will increase by $e^{0.01}$ or 1.01 times, holding all other variables constant.

In the final model, the final estimation of variance components indicates a variance component of 0.03 (χ^2 (46) = 136.79, $p < 0.001$). It can be concluded that the residual variance of β_0 is statistically different from zero. This confirms that the intercept coefficient should be modeled as random as is done in this analysis to account for variation in the intercept value across the 50 classrooms. Twenty-three percent of the between-group variance has been explained by the teacher's gender and ethnicity and the class type.

Table M10

Regression Coefficients for Number of Resources Used by Observed Students

Effect	R.I. only model		Fixed effects model		Final model	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Intercept	1.579**	0.032	1.800**	0.467	1.669**	0.338
Student's GPA			0.004	0.005	-0.000	0.003
Student's time on computer			0.009**	0.002	0.010**	0.002
Student's gender			-0.047	0.067	-0.051	0.038
Student's age			-0.014	0.037	-0.007	0.026
Student's time on projects			-0.004	0.003	-0.004	0.002
Teacher's gender					-0.002	0.063
Regular class					-0.006	0.066
White teacher					0.089	0.064

11) Outcome = the percentage of resources used that were selected at the student's own initiative rather than at the teacher's direction (PSTUDINI). Linear model specified.

For the random intercept only model it appears that the mean value of the intercept (Table M11) differs significantly from zero. The final estimation of variance components indicates a variance component of 194.77 (χ^2 (49) = 220.27, $p < .001$). It can be concluded that the intercepts are significantly different for the different classes and that further analysis is warranted to determine the source of that variation, that is, what causes students in different classrooms to use more or less resources at their own initiative. The ICC in the random intercept only model is .47 indicating that a random intercept model is merited.

Table M11

Regression Coefficients for Percentage of Resources that are Used at the Student's Own Initiative

Effect	R.I. only model		Fixed effects model		Final model	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Intercept	14.832**	2.270	-5.010	18.159	27.605	20.679
Student's GPA			-0.149	0.174	-0.111	0.188
Student's time on computer			0.818**	0.098	0.774**	0.131
Student's gender			-1.790	2.594	-0.832	2.392
Student's age			1.791	1.441	-0.477	1.592
Student's time on projects			-0.192	0.128	-0.137	0.143
Teacher's gender					-1.943	3.801
Regular class					-3.395	4.006
White teacher					-2.371	3.900

Both the fixed effects model and the final multilevel model (Table M11) indicate that more computer use in the class significantly predicts a greater percentage of resources selected at the student's own initiative after controlling for the other factors included in the models. From the final model, for a one standard deviation increase in the amount of time spent on the computer (14 minutes), the percentage of resources selected at the student's own initiative increases by 0.77%.

In the final model, the final estimation of variance components indicates a variance component of 99.25 (χ^2 (46) = 126.77, $p < .001$). It can be concluded that the residual variance of β_0 is statistically different from zero confirming that the intercept coefficient should be modeled as random as is done in this analysis. Forty-nine percent of the between-group variance has been explained by the teacher's gender and ethnicity and the class type.

12) Outcome = the number of activities the student engaged in during the course of the observation (ACTIVITI). Poisson model specified.

For the random intercept only model it appears that the mean value of the intercept (Table M12) differs significantly from zero. The final estimation of variance components indicates a variance component of 0.16 (χ^2 (49) = 134.71, $p < .001$). It can be concluded that the intercepts are significantly different for the different classes and that further analysis is warranted to determine the source of that variation, that is, what causes students in different classrooms to use more or less resources at their own initiative. The ICC in the random intercept only model is .12 indicating that a random intercept model is warranted.

The fixed effects model (Table M12) indicates that more computer use in the class significantly predicts fewer changes in activity after controlling for the other factors included in the model. More time spent on project work also predicts fewer changes in activity. The final model (Table M12) supports these two findings but also indicates that students of female teachers change activity more frequently than those of male teachers.

From the final model, for a one standard deviation increase in the amount of time spent on the computer (14 minutes), the mean number of activities will decrease by $e^{-0.02}$ or 0.98 times, holding all other variables constant. For a one standard deviation increase in the amount of time spent working on a project (10.8 minutes), the mean number of activities will decrease by $e^{-0.01}$ or 0.99 times, holding all other variables constant.

Table M12

Regression Coefficients for the Number of Activities Engaged in by Observed Student

Effect	R.I. only model		Fixed effects model		Final model	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Intercept	1.243**	0.061	1.970**	0.561	1.410*	0.597
Student's GPA			0.005	0.005	0.006	0.006
Student's time on computer			-0.018**	0.003	-0.020**	0.004
Student's gender			-0.041	0.080	-0.053	0.078
Student's age			-0.062	0.046	-0.034	0.046
Student's time on projects			-0.012*	0.005	-0.014**	0.005
Teacher's gender					0.248*	0.093
Regular class					0.055	0.099
White teacher					0.023	0.096

Students of female teachers change activity more frequently than those of male teachers by a factor of $e^{0.25}$ or 1.28 times.

The final estimation of variance components indicates a variance component of 0.03 (χ^2 (46) = 59.82, $p > .05$). It can be concluded that the level of the intercept no longer varies much among the 50 classrooms. 78% of the between-group variance has been explained by the teacher's gender and ethnicity and the class type.

REFERENCES

Adelman, N., Donnelly, M., Dove, T., Tiffany-Morales, J., Wayne, A., & Zucker, A. (2002). *The integrated studies of educational technology: Professional development and teachers' use of technology.* Menlo Park, CA: SRI International.

Bakeman, R., & Gottman, J.M. (1997) *Observing interaction: An introduction to sequential analysis.* Second edition. Cambridge University Press.

Bangert-Drowns, R.L., Kulik, J.A., & Kulik, C. (1985). Effectiveness of computer-based instruction in secondary schools. *Journal of Computer-Based Instruction 12* (3), 59-68.

Becker, H. J., Ravitz, J. L., & Wong, Y. T. (1999). *Teaching, learning and computing: 1998 National Survey Report #3.*

Black, J.B., & McClintock, R.O. (1996). An interpretation construction approach to constructivist design. In B. Wilson (Ed.) *Constructivist learning environments* (pp. 25-31). Englewood Cliffs, NJ: Educational Technology Publications.

Brophy, J., & Good, T. (1970). The Brophy-Good dyadic interaction system. In A. Simon & E. Boyer (Eds.), *Mirrors for behavior: an anthology of observation instruments continued,* Supplement (Vols. A and B). Philadelphia: Research for Better Schools, Inc.

Burns, P.K., & Bozeman, W.C. (1981, October). Computer-assisted instruction and mathematics achievement: is there a relationship? *Educational Technology 21,* 32-39.

Cognition and Technology Group at Vanderbilt University. (1992a). The Jasper series as an example of anchored instruction: theory, program description and assessment data. *Educational Psychologist, 27,* 291-315.

Cognition and Technology Group at Vanderbilt University. (1992b). Some thoughts about constructivism and instructional design. In Duffy, T.M., & Jonassen, D.H. (Eds.) *Constructivism and the technology of instruction.* (pp.115-119). Hillsdale, NJ: Erlbaum.

Cuban, L. (1986). *Teachers and machines: the classroom use of technology since 1920.* New York: Teachers College Press.

Cuban, L. (1993). Computers meet classroom: Classroom wins. *Teachers College Record, 95* (2), 185-210.

Desimone, L. M., Porter, A. C., Garet, M. S., Yoon, K. S., & Birman, B. F. (2002). Effects of professional development on teachers' instruction: Results from a three-year longitudinal study. *Educational Evaluation and Policy Analysis, 24* (2), 81-112.

Dexter, S., Ronnkvist, A., & Anderson, R. (2000). *Quality technology support: What is it, who has it, and does it impact teachers' uses of educational technology?* Paper presented at the Annual Conference of the American Educational Research Association, New Orleans.

Follansbee, S., Hughes, B., Pisha, B., & Stahl, S. (1997, Winter). Can on-line communication improve student performance? Results of a controlled study. *ERS Spectrum.*

Glennan, T.K., & Melmed, A. (1996). *Fostering the use of educational technology: Elements of a national strategy.* Santa Monica, CA: RAND, Critical Technologies Institute.

Good, T.L., & Brophy, J.E. (1987) *Looking in classrooms.* New York: Harper & Row.

Hartley, S.S. (1978). Meta-analysis of the effects of individually paced instruction in mathematics. *Dissertation Abstracts International, 38* (7-A), 4003. (University Microfilms No.77-29, 926, 1978).

Heck, R. H., & Thomas, S. L. (2000). *An introduction to multilevel modeling techniques.* Mahwah, NJ: Erlbaum.

Heinecke, W.F., Blasi, L., Milman, N., & Washington, L. (1999). *New directions in the evaluation of the effectiveness of educational technology.* [On-line]. Available: http://www.ed.gov/Technology/TechConf/1999/whitepapers/paper8.html.

Honey, M., Culp, K.M., & Carrigg, F. (1999). *Perspectives on technology and education research: Lessons from the past and present.* [On-line]. Available: http://www.ed.gov/Technology/TechConf/1999.

Hox, J. J. (1995). *Applied mutlilevel analysis.* Amsterdam: T.T.Publikalities.

Keller, J. (2000). Learning from our mistakes. *Technology & Learning, 20* (11), 60-66.

Kreft, I., & De Leeuw, J. (1998). *Introducing multilevel modeling.* Thousand Oaks, CA: Sage.

Kulik, C., & Kulik, J.A. (1991) Effectiveness of computer-based instruction: an updated analysis. *Computers in Human Behavior, 7,* 75-94.

Kulik, C., Kulik, J.A., & Bangert-Drowns, R.L. (1990). Effectiveness of mastery learning programs: A meta-analysis. *Review of Educational Research 60* (2) 265-299.

Levin, H., Glass, G., & Meister, G. (1984). *Cost-effectiveness of four educational interventions*. (Project report No. 84-A11). Stanford, CA: Institute for Research on Educational Finance and Government.

Mann, D. (1999). *Documenting the effects of instructional technology: A fly-over of policy questions.* [On-line]. Available: http://www.ed.gov/Technology/TechConf/1999/whitepapers/paper6.html.

Market Data Retrieval. (2002). *Technology in education 2002*. Shelton, CT: Author.

Marshall, H., & Weinstein, R. (1986). *Classroom Dimensions Observation System: Revised manual.* Berkeley: University of California.

McClintock, R.O. (2000). *Experience and innovation: reflections on emerging practice with new media in education.* [On-line]. Available: http://www.ilt.columbia.edu/Publications/papers/ICON.html.

McDonnell, L. M., & Elmore, R. F. (1987). *Alternative policy instruments* (ERIC Document Reproduction Services No. 293218).

McKinsey & Company. (1995). *Connecting K-12 schools to the information superhighway.* Palo Alto, CA: Author.

McNabb, M., Hawkes, M., & Rouk, U. (1999). *Critical issues in evaluating the effectiveness of technology.* [On-line]. Available: http://www.ed.gov/Technology/TechConf/1999/confsum.html.

Means, B. & Golan, S. (1998). *Transforming teaching and learning with multimedia technology.* Menlo Park, CA: SRI International.

National Center for Education Statistics. (2000). *Teachers' tools for the 21st century: A report on teachers' use of technology.* (NCES 2000-102). Washington, DC: Author.

Norris, C., Smolka, J., & Soloway, E. (1999) *Convergent analysis: A method for extracting the value from research studies on technology in education.* [On-line]. Available:http://www.ed.gov/Technology/TechConf/1999/whitepapers/paper2.html

Padron, Y.N. & Waxman, H.C. (2000) *The uses of the Classroom Observation Schedule to improve classroom instruction.* Paper presented at The Annual Meeting of the American Educational Research Association, New Orleans.

Penuel, W.R., Golan, S., Means, B., & Korbak, C. (2000). *Silicon Valley Challenge 2000: Year 4 report.* Menlo Park, CA: SRI International.

Penuel, W. R. & Means, B. (1999). *Observing classroom processes in project-based learning using multimedia: A tool for evaluators.* [On-line]. Available: http://www.ed.gov/Technology/TechConf/1999/whitepapers/paper3.html.

President's Committee of Advisors on Science and Technology (PCAST), Panel on Educational Technology. (1997). *Report to the President on the use of technology to strengthen K-12 education in the United States.* Washington, DC: United States Government Printing Office.

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierachical linear models: Applications and data analysis methods.* Thousand Oaks, CA: Sage.

Raudenbush, S. W., Bryk, A. S., Cheong, Y. F., & Congdon, R. T. (2001). *HLM5 Hierarchical linear and nonlinear modeling.* Lincolnwood, IL: Scientific Software International.

Ravitz, J. & Becker, H. (2000, April). *Evidence for computer use being related to more constructivist practices and to changes in practice in a more constructivist-compatible direction.* Meetings of the American Educational Research Association. New Orleans. [On-line]. Available: http://www.gse.uci.edu/Ravitz/aera00/Poster18/index.htm.

Ravitz, J. & Light, D. (2000, May). *A tool for assessing conditions that support educational technology reforms among U.S. teachers in grades 4-12.* [On-line]. Available: http://www.gse.uci.edu/Ravitz/cilt_project/overview.html.

Ravitz, J. & Wong, Y. (2000, April). *How teaching philosophies relevant to computer use originate: Effects of educational background, teaching responsibilities, and computer use.* Meetings of the American Educational Research Association. New Orleans. [On-line]. Available: http://www.gse.uci.edu/Ravitz/aera00/Poster17/index.htm.

Sandholtz, J.H., Ringstaff, C., & Dwyer, D.C. (1997). *Teaching with technology: Creating student-centered classrooms.* New York: Teachers College Press.

Schofield, J.W. (1995). *Computers and classroom culture.* New York: Cambridge University Press.

Simon, A. & Boyer, E.G. (Eds.) (1967). *Mirrors for behavior: An anthology of classroom observation instruments.* Philadelphia: Research for Better Schools.

Skinner, R. A. (2002, May 9). Tracking tech trends. *Education Week.* pp.53-67.

Slavin, R., E. (2002). Evidence-based education policies: Transforming educational practice and research. *Educational Researcher, 31* (7), 15-21.

Snijders, T. A. B., & Bosker, R. J. (1999). *Multilevel analysis: An introduction to basic and advanced multilevel modeling*. Thousand Oaks, CA: Sage.

Wenglinsky, H. (1998). *Does it compute? The relationship between educational technology and student achievement in mathematics*. Princeton, NJ: Educational Testing Service, Policy Information Center, Research Division.

Websites:

New York City Department of Education School Reports: http://www.nycenet.edu/daa/01asr/

Board of Education guide to Project Smart Schools: http://www.nycenet.edu/oit/pssguide.htm

United States Department of Education's Technology Innovation Challenge Grants (TICG) Program: http://www.ed.gov/Technology/challenge/index.html

United States Department of Education's Preparing Tomorrow's Teachers to Use Technology (PT3) Program: http://www.ed.gov/teachtech/

United States Department of Education's Enhancing Education through Technology (Ed-Tech) Program: http://www.ed.gov/offices/OESE/SST/edtech.html