Yerrick, R., & Johnson, J. (2009). Meeting the needs of middle grade science learners through pedagogical and technological intervention. *Contemporary Issues in Technology and Teacher Education* [Online serial], *9*(3), 280-315.

Meeting the Needs of Middle Grade Science Learners Through Pedagogical and Technological Intervention

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Abstract

This mixed methods study examined the effects of inserting laptops and science technology tools in middle school environments. Working together with a local university, middle school science teaching faculty members wrote and aligned curricula, explored relevant science education literature, tested lessons with summer school students, and prepared evaluation measures for their year-long implementation of laptops, probeware, and other scientific hardware and software. This quasi-experimental study revealed differences in student achievement, responses to pedagogy, and effectiveness of tools implemented by teachers over the course of the year. Implications are discussed for the effectiveness of laptops in science, as well as future studies identifying differences in instructional practices associated with technology tools.

National Science Achievement and the Need for Improved Science Teaching

Recent National Assessment of Educational Progress (Campbell, Hombo, & Mazzeo, 2000) scores revealed that reading scores of US 17-year-olds were not significantly different from 1971 to 1999. Although mathematics scores for 17-year-olds showed a significant, though slight (1.3%), increase from 1973 to 1999, science performances painted a less encouraging picture. The overall scores of 17-year-olds declined from 1969 to 1982, increased modestly from 1982 to 1992, and have since leveled off. The 1999 end-of-the-study levels of science for 17-year-olds were significantly below (3.4%) the 1969 beginning-of-the-study levels (Campbell et al., 2000). An analysis of student reading skills revealed that average US 15-year-olds read as well as their peers in 27 other countries that make up the Organization for Economic Cooperation and Development, but perform nowhere near the top.

In mathematics, students attending high school physics since the beginning of the 21st century slightly exceeded the average international samples. Fewer than 25%, however, were proficient in math skills appropriate for their grade level. Although international comparisons in science show US students yielding better-than-average results, overall findings are disappointing. Science performance has not improved in the past decade, and fewer than a third exhibit science concepts and skills appropriate for their grade level. Clearly, across each of these academic areas, schools are not supporting the learning needs of all science students (National Center for Education Statistics, 2002).

The Third International Mathematics and Science Study (1999) studied global trends in math and science education achievement and curriculum with a focus on fourth- and eighth-grade science and mathematics. In the 1999 report on science, eighth-grade US students ranked significantly below 14 countries, were statistically even with five, and were significantly higher than 18 countries. This middle of the pack placement was not a flattering portrayal of the U.S. education system and prompted many reports, including one entitled *Before It's Too Late* (Glenn, 2000).

Calls for Science Education Reform

One response to the emergence of such startling numbers was the No Child Left Behind Act, which aimed to improve the performance of US primary and secondary schools through more rigorous standards of accountability. It has shaped the ways curriculum is delivered, how students view learning, and how teachers interpret their success in teaching.

Often called "standards-based" educational reform, its goal was to establish high standards for all children through accountability for teachers' professional preparation and measurement of student learning through increased standardized testing. The underlying principle was that setting lofty goals would improve the performance of all students. One key component to this legislation was improving teacher quality by insisting that teachers were highly qualified. The measure for highly qualified focused on minimally achieving a bachelor's degree, teaching only in areas of their major or minor, or passing rigorous academic state tests.

Though no one disagrees with the focus on achievement as a goal for science education, few agree on a definition. Typically, reformers mean a continual focus on curriculum standards, funding, policies, and billions of dollars of reform, with standard assessments as a main indicator of value and thrust for future directions. All of these drive teacher instruction in one way or another. Another interpretation, however, may be drawn from the perspective of teacher educators and university science education professors vested in producing future science teachers. For teacher educators this gap presents an opportunity to study how best to engage children in science with creative pedagogy and tools more responsive to children's attributes and needs.

Part of the discussion among science teacher educators has focused upon technological implementation to improve instruction. In fact, technology has been promoted as an appropriate tool for teaching current K-12 students for a variety of reasons, including its ability to provide familiarity with tools students use outside of school (*Achievement for All Children: An Apple Perspective*, 2003; Lenhart et al., 2003; Lemke & Martin, 2004), to provide better training opportunities for future jobs (Tapscott, 1999; Partnership for 21st Century Skills, 2005), and to provide venues for better inquiry teaching (American Association for the Advancement of Science, 1990, 1993; National Resource Council [NRC], 1996).

Some authors have argued that US teens in today's schools need new tools for learning because there are fundamental differences in current American culture and the way students learn best (Friedman, 2005; Pink, 2005). For example, according to the Pew Internet & American Life Project (2005), 87% of children ages 12 to 17 use the Internet regularly. This number has increased more than one fourth since the year 2000. Seventy-five percent of today's teens use at least two digital devices daily and spend an average of nearly 6.5 hours a day with media. Such observed changes in student behavior may suggest a false hope and a quick fix for educators eagerly looking to incorporate technology familiar to students as a way to stay consistent with Dewey's (1956) challenge that we use the same psychology in schools that we apply to learning outside of schools.

Though the arguments are compelling, educators must consider carefully what current research says and what has not yet been answered. Such arguments ignore the fact that other nations to which the US is being compared are investing less resources in technology than is the US. Oppenheimer (2003) and Cuban (1986, 2001) have clearly offered important challenges to the notion that technology is an automatic improvement in classrooms. They said that many of the claims that technology should be integrated into school learning environments are not based upon empirical evidence about students or learning environments.

Yet the growth and investment in technology by the US is increasing. According to Abd-El-Khalick and Waight (2007) the rapid integration is not always based upon established research, and often the research available to make important technological implementation decisions does not take a critical eye when viewing the use of technology or the specific focus for specific interventions in using technology to promote inquiry. Though compelling, science educators must consider carefully which tools assist in promoting science inquiry and how these can be thoughtfully incorporated into instruction in ways that add value to science teaching.

Considerations for Technology Implementation in Science Instruction

Some researchers have argued that meeting *National Science Education Standards* without technology would be difficult (Metcalf & Tinker, 2004; Lento, 2005), but which tools should be considered? Researchers argue that data guiding decisions of implementation ought to be critical in perspective and related specifically to the context in which they are applied and not based upon dissimilar educational contexts (Abd-El-Khalick & Waight, 2007; Ballone & Czerniak, 2001; Czerniak, Lumpe, Haney, & Beck, 2001). One important research finding that confounds the notion that inserting technology will raise science student test scores is the research on teachers' poor implementation of technology. Oppenheimer (2003) described at length his observations of teachers allowing the technology to be the focus of instruction instead of the content it is meant to teach. The focus on adding sound effects, transitions, and meaningless pictures to presentations is but one of many examples of how inappropriate teaching strategies can wrongly emphasize the tool over the learning.

As Mehan (1989) and more recently Cuban (2001) have described, classrooms reflect the social values of the teachers and students who inhabit them, and the artifacts (computers) simply take on the roles that fit those learning environments. If a science teacher's epistemological orientation toward science is a collection of facts, then the computer is likely going to become a tool that collects, organizes, and repeats facts more efficiently. Obviously, this approach is not an improvement toward national reforms challenging teachers to a more inquiry-based approach to science instruction.

Teachers' orientation toward science learning is one of the primary factors that must be attended to in any technological implementation. It has been well documented by several researchers that making changes toward a constructivist orientation in teaching is more difficult than simply learning new technologies (Becker & Riel, 2000; Rakes, Flowers, Casey, & Santana, 1999). For example, in a recent survey of 655 teachers (grade 4 to 12), Becker and Riel (2000) found that less than 4% of the teachers surveyed used computers during instruction to assist students in constructing their own understanding of content knowledge in accordance with constructivist learning frameworks.

In addition Rakes et al. (1999) found that in a survey of 435 teachers who use technology in K-12 contexts, less than half of the teachers who professed to be constructivist acknowledged implementing 6 out of 14 commonly identified constructivist strategies. Furthermore, only 40% of the participating teachers used even three of these strategies, and less than 20% of those who claimed to use constructivist strategies in their classrooms implemented them "fairly often" (monthly). Clearly, providing technology in science classrooms is insufficient for making needed change. In addition, providing technical and professional development support will not likely effect longlasting change even for self-reported constructivist teachers (Becker & Riel, 2000; Cuban, 1986; Rakes et al., 1999).

Few empirical studies focus on the process of using technologies in elementary and middle school science classrooms and how these technologies function within the expectations, norms, and practices in current classrooms. Considerations for integrating computers in science classrooms include (a) students' skills, attributes, and needs, (b) teacher professional development opportunities, and (c) desired learning outcomes.

Student Skills, Attributes, and Needs

Different science students bring their own repertoire of skills, knowledge, experiences, attitudes, and assumptions to the classroom, and no single teaching strategy best suits all students (Coffield, Moseley, Hall, & Eccelstone, 2004; Duff, 2002; Dunn & Griggs, 2000; Felder & Silverman, 1988; Kolb & Kolb, 2005). Learning style theory has been applied to a variety of learning environments and can be defined as the manner in which students of all ages are affected by sociological needs, immediate environment, physical characteristics, and emotional and psychological inclinations. Having teachers learn about different learning styles of students and how they relate to technology implementation can help science teachers make better decisions about teaching strategies and which tools best can engage which students.

Differences exist among and between student groups, and not all curricula or technological innovations developed by teachers or science experts should be expected to achieve similar ends for all students. A teacher's individual learning style or favored teaching style may also be different from many of the students' learning styles. When the teacher is not aware of students' learning styles, the cognitive and psychological impact can be negative toward learning (Keefe, 1982). Dunn and Dunn (1992) suggested that research on learning styles provides insight for teachers to address the needs of individuals through matching styles or capitalizing on students' personal strengths.

Technological implementations for students should consider ways that tools can expand opportunities to all students by offering different kinds of access to knowledge. Incorporating into science lessons opportunities for students to demonstrate science competency through musical, dramatic, artistic, or other representations is one way to honor students' diverse skill sets. Orchestrating collaboration of diverse student knowledge and skill sets around a central problem or concept can also offer greater opportunity for success in classrooms.

Becoming familiar with differences in learners' specific styles of preferred knowledge acquisition allows in-depth understanding and interaction with the interests and needs of a greater diversity of students. Research studies confirm the need for identifying each student's preferred learning style and for teaching in ways that complement that style (Duff, 2004; Dunn & Dunn, 1992; Dunn & Griggs, 2000; Felder & Silverman, 1988; Kolb & Kolb, 2005).

Academic achievement is elevated when teachers use instructional strategies consistent with students' preferred learning styles (Ballone & Czerniak, 2001). In the converse, students tend to achieve lower when their learning style and environment are mismatched (MacMurren, 1985; Pizzo, 1981). In fact, some have even argued for a direct correlation between the match of learning styles and environment and student grade point average (Cafferty, 1981).

To achieve the goal of having all students succeed in science requires teachers' practices and curriculum content to meet students' various interests, abilities, experiences, understandings, and knowledge. Accepting diversity in learning styles means also accepting that all students can learn, and effective teachers consider both the content to be learned and the learning context, including the background of the students. Instructional materials must be designed to be not only flexible, but also supportive of diversity and capable of accommodating a wide range of learning styles (McLoughlin, 1999). Technology integration has been said to initiate the desired curricular and pedagogical change given the opportunity, equipment, and support (Wetzel, 2001).

Teacher Professional Development

Technology insertion into classrooms, in and of itself, will not likely result in any positive change toward inquiry. Teachers need support, incentive, and practice in applying new pedagogical and technological innovations. Science teachers generally agree that technology should be incorporated into science instruction, but most are passive about seeking professional development in technology or finding time to learn new strategies and tools (Odom, Settlage, & Pedersen, 2002; Pedersen & Yerrick, 2000). In fact a major gap exists between science teachers' desired versus actual use of technology in most science classrooms. Researchers argue that the vast majority of teachers have had little or no formal training on how to apply computers specifically to their science content teaching (Berger, Lu, Belzer, & Voss, 1994).

Such findings support prior research indicating that a significant amount of practice and training are needed before teachers become comfortable with the use of technological tools to facilitate student learning (Gado, Ferguson, & van 't Hooft, 2006). Although resistance to change in science teaching practices remains high, research supports teaching practices that consider students' learning styles through the use of technology to improve the quality of both teaching and learning (Ballone & Czerniak, 2001; Grasha & Yangarber-Hicks, 2000).

Constructivist teaching methods can be as influential in improving student learning as any technology intervention and can enhance student engagement in classrooms. Study after study has demonstrated that it is not the technology tool that makes the difference, but the willingness of teachers to change their classroom practices that causes the greatest impact on learning (Cuban, 1986; Quinn & Valentine, 2001; Wenglinsky, 1998;

Yerrick & Hoving, 1999). Despite the reports that teachers are open and willing to try technological innovations in their science teaching (Czerniak et al., 2001; Pedersen & Yerrick, 2000), studies show relatively low rates of classroom transformation (Becker & Riel, 2000; Cuban, 1986; Rakes et al., 1999).

Younger generations are presumed to have a greater affinity for and ability to use technology, but researchers found that novice teachers were generally cautious about implementing technology into teaching (Gado et al., 2006). Teachers instead felt it important to present both traditional and technology enhanced experimentation, demonstrating how new technologies foster critical thinking and simplify experimentation and improve reliability of data. Paradoxically, these same novice teachers felt that proper training for both teachers and students on the use of new technological tools was essential to their successful integration and would not feel comfortable teaching without it.

Student access and devoted on-task time with the tool also are necessary considerations for teachers and students. In data from student pre- and posttests, Metcalf and Tinker (2004) found significant increases in scores associated with the use of probeware in science. Maximum gains were observed when extended time was provided for use of the tools, and minimum gains were found when use was rushed. Teachers reported that students learned more with the use of technological tools and found that the direct experience of doing the activity was particularly beneficial. Students were able to confront their misconceptions and improve graph-reading skills while learning science content. These findings were also confirmed through classroom observations. Students stated in interviews that they learned science better using technology than they had with activities in other science courses. These gains were limited by a lack of availability of equipment and time due to sharing of tools and resources.

Research Questions

The goal of our study was to examine the effects of inserting laptops and science technology tools into middle school environments while providing responsive professional development in the classrooms of motivated middle school science teachers. For the 2007-2008 academic year, one middle school offered the opportunity for teachers to learn the tools, associated pedagogical strategies, and curriculum throughout the year, as student engagement, achievement, and perceptions were studied in collaboration with the local university.

Beginning in the summer and throughout the year a small group of middle school science teachers explored exemplary tools and strategies to engage children more and help them learn science in ways consistent with science education and technology education reform visions. Working together with a local New York university (LNYU), science teaching faculty member wrote and aligned curricula, checked out LNYU equipment, explored science education literature, tested lessons with summer school students, and prepared evaluation measures for their 2007-2008 implementation of laptops, probeware, and a host of other scientific hardware and software. As we had the opportunity to study different teachers in the same middle school environment covering the same curriculum but using different tools and teaching strategies, we considered the following research questions:

- What is the impact on students' learning and science knowledge when teachers employ inquiry pedagogies with technological tools?

- How do students perceive themselves as learners and their teachers' efforts with technology to improve science teaching?

- Which educational technologies do students perceive as helpful in learning science?

Methodology

This study was conducted at a suburban middle school, located in the state of New York. This school was selected for this study because of its involvement with an ongoing teacher education program and the strength and experience of its science teachers. Teachers within the middle school had relatively little access to classroom technology, so we could invite teachers into the study and monitor precisely how laptops were used in science instruction. There was one personal computer (PC) on every teacher's desk and an outdated PC laboratory with fewer than two dozen machines for over 500 students. Figure 1 displays the the student to computer ratio for students during the year of the study and prior years.

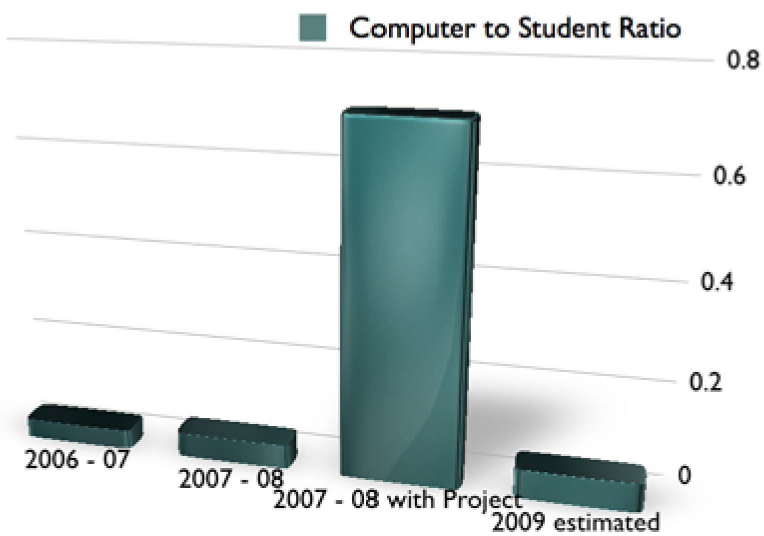

Figure 1. Computer-to-student ratio for middle school 2 years prior, the year of the intervention, and the projected year following the project.

The entire science department of the participating middle school was invited to participate in training and the equipment loan program at the target middle school. Of those teachers, only two of the ten science teachers chose to fully participate in the training, planning, and implementation of the technology tools and new teaching strategies. Fifteen MacBook computers were provided to the school, increasing their computer to student ratio (see Figure 1). The two participating teachers (one earth science and one physical science) were also provided a laptop from the district with a complete station of probeware and software for participating teachers.

Throughout the 2007–2008 school year, researchers received full access to classrooms, achievement scores, and artifacts, as well as to the students for interviews. Because all 10 science teachers at the school were aiming for the same goal— New York Regents Examination competency—the 8 teachers who self-selected out of the study provided a quasicontrol group of students who did not have access to technology. This context also provided an excellent opportunity to gather data regarding the technology implementation from the students' perspective, contrasting with their past experiences learning science without technology in the classroom.

In this study, a case is presented in which science teachers attempted to address the needs of their students through participation in a new technology integration and inquiry pedagogy project. The teachers accompanied the technology implementation with inquiry-based teaching strategies in their earth science and physical science classes. During this yearlong implementation of instructional technologies, including PASCO probeware, the ProscopeHR, iPhoto, Macbooks, Datastudio software, Garageband, and other tools, the teachers and university faculty members involved measured in a variety of ways how successful they had been in addressing the various needs of their students.

The two main purposes were emphasized for the implementation of technology in the science classroom: (a) the insertion of actual data to complement instruction and laboratory investigations and (b) the use of media creation tools to give the students opportunities to co-construct knowledge of abstract concepts. To match the science learning environment with that of students' daily lives, teachers began borrowing weekly digital tools from LNYU and employing new teaching to give students access to the kinds of tools they know, understand,
and use daily.

Pedagogical and Technological Intervention

There are a variety of instructional goals teachers may hold for their students in science classrooms, ranging from acquiring concepts to learning to devise science experiments. The *National Science Education Standards* called for students to be able to "develop abilities necessary to do scientific inquiry...[and] use technology and mathematics to improve investigations and communications" (NRC, 1996, pp. 175). Technology may assist traditional teachers in drill and practice, and most technological implementation has been reported to have served very traditional purposes in classrooms (Berger et al., 1994; Cuban, 2001; Oppenheimer, 2003).

Training time has not been the only concern, but also the time that the tool is available to the student. In data from student pre- and posttests, Metcalf and Tinker (2004) found significant increases in scores associated with the use of probeware in science. Maximum gains were observed when extended time was provided for use of the tools, and minimum gains were found when use was rushed. Teachers reported that students learned more with the use of technological tools and found that the direct experience of doing the activity was particularly beneficial. Students were able to confront their misconceptions and improve graph-reading skills while learning science content.

These findings were also confirmed through classroom observations. Students stated in interviews that they learned science better using technology than they had with activities in other science courses. These gains can be limited by a lack of availability of equipment or a lack of time due to shared tools. A curriculum that specifically supports the use of handheld computers or probeware would help in acquiring these types of tools. Schools will be less resistant to purchasing equipment if the equipment is part of the written curriculum (Gado et al., 2006).

Purposeful Implementation of Tools

There are a variety of purposes and goals teachers may hold when implementing technology. Teachers in this project sought ways to improve upon areas of their teaching where achievement scores had consistently lagged over 5 years. They sought to make more personal applications of content, incorporate tools that were familiar to students, provide tools to help students in the process of coconstructing meaning in science, and insert problem-solving strategies using data whenever possible to give students an important context to discuss covered science concepts. Three specific areas were targeted for the use of technology in their teaching:

Use of Technology for Problem Solving. Middle school science teachers devoted weeks of their 2007 summer break to explore inquiry methods for teaching that incorporated technological tools for scientific data collection and analysis. Using their past New York Regents scores to direct their efforts, teachers developed lessons, labs, and projects that would promote problem solving and critical thinking about real world data. Lessons included the use of global databases maintained by the U.S. Geological Survey, force and motion detectors, temperature probes, weather sensors, and scientific models and simulations of concepts students learned in physical and earth science. Teachers also developed assessments and rubrics to assess students' knowledge for each of their planned innovations.

Use of Technology for Media Literacy. Educational research has demonstrated that students are busy continuously coconstructing knowledge in classrooms. Students were given several opportunities to express their unique knowledge through multiple venues. Students created podcasts, iPhoto books, slideshow presentations and other artifacts displaying their knowledge using the MacBooks and the built-in iLife suite.

Use of Technology for Critical Thinking. In a typical week when science projects were assigned, computer logged records and field notes confirmed that every one of the university's loaned computers were signed out and used every hour of every day, including lunch and before school. Science teachers employed problem-based learning strategies requiring students to collaborate, gather data, and propose solutions using scientific and communication tools. Solving a murder mystery by analyzing sand samples from around the world using the digital microscope, predicting weather patterns using their own probe and weather blog, and creating their own Jeopardy game using digital images and mineral tests were but a few innovations teachers used to promote inquiry in their classroom.

Use of Technology Tools Promoting Inquiry. Throughout the year laptops, probeware, software, and digital microscopes and cameras were inserted into classroom lessons through a variety of instructional strategies. One particular example that students mentioned often in the debriefing focus groups was the use of the digital microscope, Keynote, Google images, and Garageband. The teachers organized ways to have students create mineral reports and present their findings in a jigsaw strategy. Time during class was spent in reporting research students had gleaned from their book, their library, and the Internet and found images or created representations that best expressed their learning. Following the completion of their podcasts (e.g., see Video 1), students used one full class period to share and discuss their projects.

Although lectures and labs supplemented these student projects, students most noted their ability to present information in ways that made the most sense to them. As an assessment strategy devised by one of the teachers, students then used the digital microscope to gather images of the rocks and minerals in a variety of magnifications to display such concepts as grain size and composition. These images were then used to create a Jeopardy-style game show, where students competed against one another in class to prepare for the exam. This kind of strategic use of the tools to demonstrate content, promote exploration, and encourage students to restate content in ways that best suited their learning styles were typical of the year's activities.

Teachers continued to learn new ways to engage children in science through exemplary strategies and tools, and probeware was also a central tool to the science classroom. Concepts like phase change in states of matter, heat of fusion, heat of vaporization, and the conservation of energy are all challenging and abstract concepts. Labs associated with phase changes and heat transfer often gave wide ranges of error each year and led to many misconceptions among students. Probeware allowed students to gather live data quickly with minimal time for lab setup and to analyze findings in the same class period. Using the stainless steel temperature probes allowed students to heat ice in a beaker with consistent temperature readings without stirring vigorously—a task impossible with standard glass alcohol thermometers. They used these probes in other labs as well to monitor live data, scale their graphs, and share their work electronically.

Data Analysis

All of the students enrolling in science were invited to participate in a survey regarding their use of technology at home and at school. More than 500 students from all the science teachers' classrooms responded to this survey, as well as a self-assessment of their learning style and for the observed teaching styles of their science teachers. Test scores and surveys of learning styles and attitudes were administered anonymously for all of these students, so as not to taint the selection of students sampled or influence their reports of teachers' pedagogical practices. The project teachers' students were disaggregated from the other 8 teachers' students to compare their learning styles, observed teachers' strategies, use of technology, and achievement data. The survey instruments used were the Learning Environment Inventory (LEI) and My Class Inventory (MCI) published by Fraser (1982; see example items in Appendix A). Students were prepared for self-assessments of learning styles through a Web instrument published by the Birmingham Grid for Learning (2002).

To explore more specifically how technology was employed in the project teachers' classrooms, interviews and focus groups were conducted and comprised of questions regarding students' use of technology, questions regarding the classroom context, and probes to elaborate on the students' responses to the surveys. Project teachers' students were also asked to respond regarding the value of specific tools for learning specific concepts. These questions were not asked of students outside the project, as their teachers chose not employ the loan equipment. To better understand the implementation of technology during instruction, we also gathered field notes, conducted debriefing interviews with project teachers, and interviewed their students in individual settings from 45 minutes to an hour regarding specific observed lessons and general perceptions. Focus groups were also conducted to filter out the individual versus collective consciousness of the classroom interpretation. Over 30 hours of interviews were transcribed, and themes were initially identified prior to specific applied coding. Project teachers were consulted in interviews regarding these potential themes, and follow-up interviews were conducted when discrepancies occurred.

Taking into consideration the age of the students being interviewed, one possible threat to credibility and verifiability would be student hesitation to say negative things about a teacher to a perceived authority figure. A conversational tone was maintained throughout the interview, establishing rapport but trying not to cross over into the "we" mentality described by Seidman (1991). Furthermore, the protocol included built-in redundancy and repetition in the questioning, giving students chances to support or refute their previous statements.

Interviews were recorded digitally, and after review selected sections were transcribed for analysis. (See Appendix B for the interview protocol.) Transcriptions were analyzed for recurring themes, using the NVivo program, with regard to the research questions. Themes were identified and specific quotes were drawn from the transcripts. These themes led to the creation of assertions.

Data from pre- and posttests and from the student survey were imported into SPSS for statistical computations. Pre- and posttest significance were analyzed using a repeated measures ANOVA. Statistical significance of mean differences between project classrooms and nonproject classrooms on student survey responses were analyzed using *t* tests. For all statistical analyses, an initial a of 0.05 was used with the appropriate Bonferroni adjustment. Surveys were analyzed by comparative *t*-test scores.Validity and reliability results are reported for each finding where statistical significance was found. Other quantitative data were compiled with qualitative results in a mixed methods approach to refute or confirm conjectures put forth by researchers.

Findings

Findings are presented according to grouped themes: (a) student attributes, (b) teacher use, (c) student achievement, and (d) student responses to technology implementation. Student achievement data, student interviews, student surveys, and supplemental teacher interviews tell a more cogent story when told together.

Student Attributes

There are many descriptions and generalizations found in the literature about today's science students. They have been called Digital Natives, Hyper-communicators, Multi-taskers, and many other attributes which define them technologically. Current technology education literature tends to overemphasize student characteristics as defined by tools rather than by emotional, academic, or sociocultural characteristics students place upon themselves.

For example, as reported in the 2005 Pew Internet & American Life Project, 75% of today's teens use at least two digital devices daily and spend an average of nearly 6.5 hours a day with media. Yet, the middle school in this study had postponed plans for technology purchases in the new building pending budget approval, leaving fewer than 4% of the students access to computers at any one time. We questioned what sense the students made of this situation rather than immediately faulting the school for their limited provision of computer access. It turned out that students reported missing access to computers in their classrooms. These kinds of reservations to judgment were important in telling a more authentic story of students' perceptions.

As researchers interested in both providing students with exemplary technology and studying the impact, we tried to match the science learning environment with that of students' daily lives, so teachers began learning to use borrowed equipment like MacBooks and digital science learning tools from the LNYU to employ new teaching pedagogies and give kids access to the kinds of tools they knew, understood, and used daily. We sought to characterize students in the ways they *saw themselves*. We questioned whether or not the students in our study actually owned or used technology and whether or not they saw teachers using technology in their classrooms in appropriate ways. Students were asked to report on the amount of technology they used at home, in science class, and in other science classes they attended.

Consistent with previous reports, students surveyed at the conclusion of the implementation used a variety of technology for a wide range of purposes, from doing homework to downloading music to conducting research for reports and making slideshow presentations. Students reported their use of cell phones and gaming devices as well as their typical technology use in a day. Though it was speculated from observations of students' behavior (e.g., texting and instant messaging) that students used technology more often than their teachers did outside of school, we did not collect data until the end of the first year.

At the end of the first year's implementation, there was a notable difference between the teachers' home use of technology and that of students home use. However, there was a statistically significant difference found between the project and nonproject classes in the reported amount of time a computer was used in class ($t_{719} = 5.056$, $p < 0.005$, $d = 5.04$), with students in classes taught by project teachers reporting more frequent use. Though both project and nonproject teachers demonstrated different uses of technology in and out of school, the contrast between similar technologies used in and out of school for the nonproject teachers was far more dramatic.

It has been argued that students have the skills to access, download, and manipulate learning resources, so lack of technology knowledge is not an impediment to using these resources in the classroom. It has also been reported that science students have a plethora of digital media devices at their disposal and are often more expert than adults in the same home who may even have purchased those devices (*Achievement for All Children: An Apple Perspective*, 2003). Students in the study reported using their cell phones, computer to complete homework, email to communicate with friends, and presentation and Internet research tools to complete class assignments. They watched television multiple hours per day, but their use of other tools was more limited. For example, students self-reported less iPod use than use of their computer, television, or cell phone. Students also reported less MySpace and Facebook use than texting, instant messaging, email, and personal gaming.

The technology utilized during instruction was very different and far less frequent than students' home use. Project teachers (as reported by their students) used the Internet for online homework and presented items found on the Web and presented static slideshow presentations and videos shown via the television. The simple appearance of the diagrams (see figures 2 and 3) shows a dramatically different technological culture two which students must acclimate in and out of the science classroom.

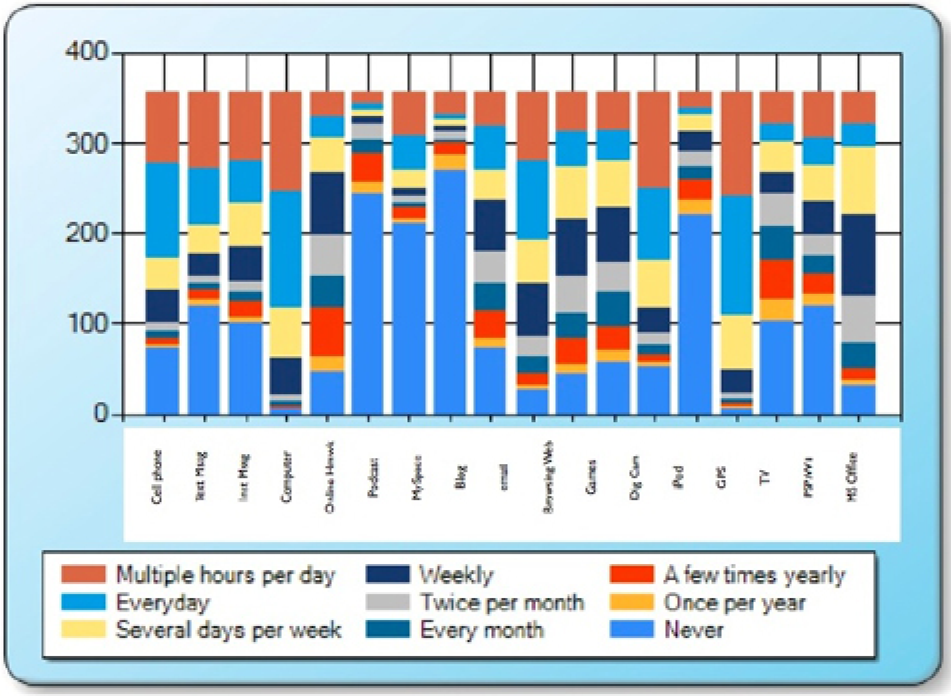

Figure 2. Students' technology use outside of school.

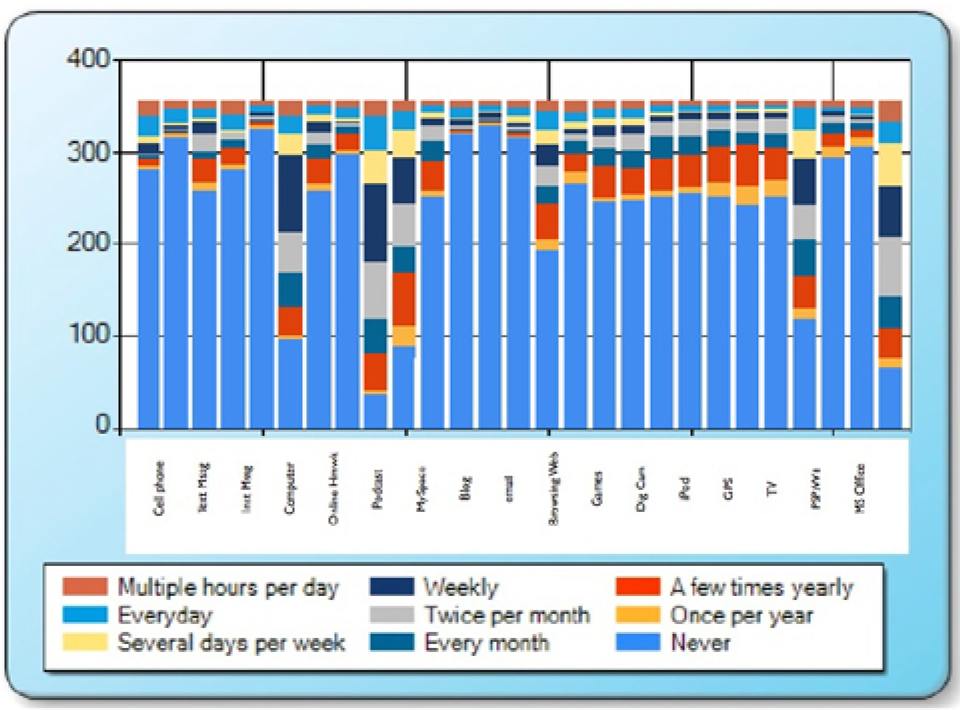

Figure 3. Students' technology use during school.

The way students learn from technology is as different and varied as their typical use. For over a decade educational researchers have heralded learning styles as descriptors for student variance and recommendations for effective teaching strategies. Their ability to describe differences accurately among students and provide formative feedback for teachers aiming to increase their impact with diverse students has provided a foundation for all children to succeed through the recognition that not all students learn in the same way.

We sought ways that students could define their own learning strengths in ways that have been discussed by educational theorists and asked students to assess their own learning styles using an online evaluation prior to collecting formal survey data. We assisted teachers in their thinking about diversity by sharing this data with them and discussing a variety of teaching strategies rather than operating on the assumptions about learners populating their classrooms.

Project teachers began to use formative assessments of their students to gauge how their methods were reaching children. Of the more than 508 science students surveyed, less than 15% identified themselves as logical-mathematical or verbal-linguistic kinds of learners. These results are shown below in Figure 4 and show all the sampled learning styles and relative percentages.

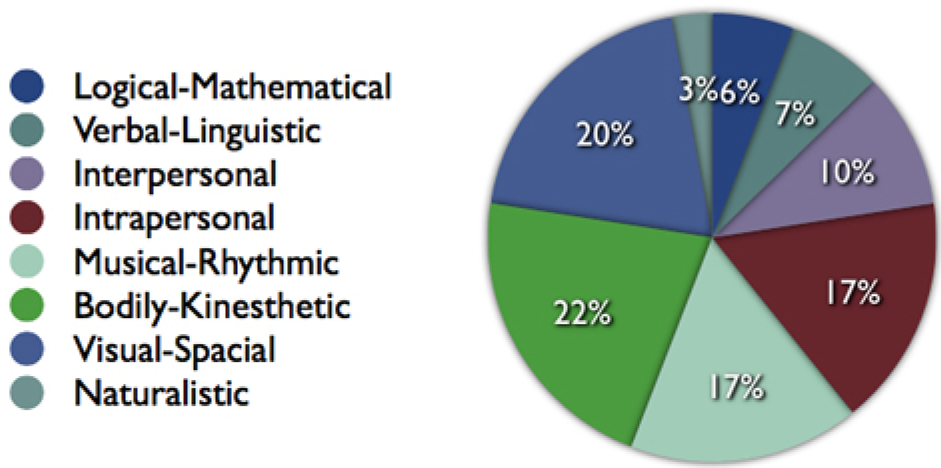

Figure 4. Students' self-reported learning styles for all science students attending the target middle school.

Few students rated themselves as strong in areas that traditional science instruction emphasize through the use of lectures, notes, and textbooks. By these findings, teachers using these strategies exclusively would meet the learning needs of only a small percentage of students surveyed. More than 40% of students identified themselves as either visual or kinesthetic learners, and they would be left out with a monolithic teaching approach.

The most prominent learning styles widely shared by students was the hands-on, kinesthetic kind of learning experience and the visual learning experience.The "traditional" conception of teaching science (e.g., memorization and repetition of scientific facts) addresses neither of these styles. The teaching strategies most closely associated with kinesthetic learning style include hands-on labs, manipulations, interactive simulations, and demonstrations.

The second most widely shared learning style identified was the visual learning experience. Some teaching strategies most closely associated with this learning style that we shared with teachers were the use of pictures, active simulations demonstrating changes over time, and graphical/visual representations of trends. Student shared how these tools and strategies helped them. Janet, for example, described how the teacher's use of the tool helped her in her visual, hands-on preference for learning:

Originally, we would have drawn the graphs yourself [sic], and that helps too, but seeing it appear on the laptop screen is really cool for me, because I never used this type of technology before, and also the [probes] and the screens on the machines for the [probes], I like looking at those and it helps me remember it better when I can see it.

The student mentioned how both the novelty and the inherent properties of the tool (being able to see the graphs as they are created) helped her to learn. Again, the activation of the visual learning style was interpreted by Janet as a superior way of learning to hearing the information only. Through this activation, Janet actively constructed her own knowledge that helped her remember it for her test. She was able to connect what she learned in the lecture to a real-world situation in ways that she knew she would not by memorizing facts and theories.

Students of the project teachers were more than twice as likely as students of the nonproject teachers to say that their teachers' strategies helped them in their particular learning style. Further, students were also more than twice as likely to say that their teachers were preparing them for the future. This is an important but underreported finding in technology studies, particularly in science.

With the technology it was easier to see the different phases of the stream table. If you were thinking about that specific lab, then it would be looking at it from interval to interval. You could compare it without having to remember what each looked like. So it really helped. (Jennifer)

The technology made it easier to both gather and understand the information, because it was presented in a way the students preferred. Students felt that technology helped facilitate their learning in ways that they had not experienced in previous years.

Interviewer:	How does the way you are learning now compare with those other years you have been talking about?
Britany:	Well, I am learning more quickly, so it's kind of easier and for some reason it is easier to learn with technology than without. It is hard to explain but you just do...because if you didn't have technology you wouldn't have the cameras or the video cameras to be able to, so we would see it once and then vanish from your brain, but we could watch it over and over again and refresh our brain on what happened.

For Britany, retention and testing was a strong reminder of how she saw herself in science because of the New York Regents examination process, on which Britany had historically done poorly as a student in prior years. Student after student indicated that specific tools helped them meet individual needs. Without them, learning and retention would have been limited. Although retention was not a high priority for the professional development offered, nor the intention for the design of tools employed, this district heavily emphasized test scores as indicators of success. The New York State science tests' predominant form of assessed knowledge is factual and requires significant retention. Teachers felt the pressure to maintain high scores.

Science Teachers' Use of Technology

There are a variety of purposes and goals teachers may hold when implementing technology. In light of the discussion of 21st Century Skills (Partnership for 21st Century Learning, 2006) teachers in this project sought ways to improve upon areas of their teaching where achievement scores had consistently lagged for their students in physical and earth science. Teachers used data collected over 5 years on specific concepts tested by the New York Regents Examination to devise lessons to address targeted concepts through varied teaching strategies and learning technologies.

Teachers sought to make more personal applications of content, incorporate tools that were familiar to students, provide tools to help students in the process of coconstructing meaning in science, and insert problem solving strategies using data whenever possible to give students an important context in which to discuss covered science concepts.

Through testing week and infrequent activity days, laptops would remain in their mobile case. In a typical week when science projects were assigned, computer logged records and field notes confirmed that every one of LNYU's computers were signed out and used every hour of every day. Logs even revealed that more than half of the laptops were checked out to students to complete work during lunch and before school hours. As a result of this extra time outside of class instruction, laptops were in use and checked out more than 100% of the instructional time. For 15 MacBooks that translated into more than 90 hours of use per week. Science teachers employed problem-based learning strategies requiring students to collaborate, gather data, and propose solutions using scientific and communication tools. One teacher said,

I believe the infusion of technology into my science class has been a positive, beneficial, and exciting experience. I see that there are real-world applications to the techniques and tools that I am teaching my students. They will continue to use and improve these skills as 21st century learners.

Project science teachers said that their students' accounts reflected that using technology was novel, but more importantly, that certain aspects of the technology were inherently helpful to them for learning science. Noting not only students' comments but also students' behaviors, teachers saw increases in students' motivation and academic achievement as their students expressed appreciation and use of other learning styles, rather than just being told information. Teachers involved in this project received dozens of hours of professional development during the summer and not less than 5 hours weekly of teaching and technology support throughout the year. It is no small feat to raise the bar for students, especially in an already high expectation environment. However, science teachers did not grow tired from their enormous investment and remained dedicated to personal growth and helping other teachers learn what they learned.

The students apply learned concepts by analyzing data, reporting their findings, making podcasts, movies, and slideshows about science. Using their 21st century skills students have created digital media artifacts that go beyond memorizing facts. The ability to share their thoughts, ideas and knowledge has been widened by the ability to share their work with family and friends across the country by publishing it to the web. They are proud of their work and are eager to show friends, as well as family and their friends what they have made. They are seen as resources to their family and the community as they show others how to express themselves and create their own media. Our students are a positive peer influence on each other. The students see that quality work is featured and have high expectations of themselves and each other. (Project Science Teacher)

Through this activation, students began actively constructing knowledge and were able to connect what they learned to real-world situations in ways that would not be possible through memorizing facts and theories. Students wrote and edited books, lab reports, podcast scripts, presentations, and even fictional and creative writing examples with the expectation that their work would be shared with parents and others. Students were eager to share their work. The students increased their skills using creative ways to communicate and express the content that they learned, consistent with the calls for reform like those of the Partnership for 21st Century Schools. As reported by one teacher, "I have never had my students writing more in my class than they have this year. Integration continues to be a strength for our school, and our students' experience has definitely been enriched."

Students want their learning environment to match the strengths, knowledge, and experiences they bring with them to school. Yet, there was a great disparity between the kinds of tools and resources middle school science students used outside the classroom versus in the class. When teachers in this project changed their routines, students noticed. Students in the project science classrooms were twice as likely as students in the nonproject classrooms to report that their teachers incorporated enough technology in their teaching (see Figure 5).

All students were asked to comment on a survey adapted from Fraser's My Classroom instrument with additional queries specific to the technological implementation and constructivist teaching strategies. As seen in Appendix B, this survey included questions regarding not only how often their teachers used the technology, but also whether or not their strategies met their individual needs, and whether their teachers' strategies and use of technology prepared them well for their perceived future.

A statistically significant difference was found in the extent to which students felt that their teachers were preparing them for the future ($t_{719} = 2.029$, $p = 0.028$, $d = 2.20$), with students in classes taught by project teachers reporting more agreement that they were being well prepared. A statistically significant difference was also found in the reported frequency of technology use in science class ($t_{719} = 5.564$, $p < 0.005$, $d = 5.61$) with students in classes taught by project teachers reporting more sufficient use of technology. In addition, a significantly greater number of students strongly agreed that their teacher "used methods that matched my learning style" and "used a good balance of teaching strategies" during science instruction. Clearly, the shift in science teaching was aligned with the needs of teen students who responded to their teachers' efforts.

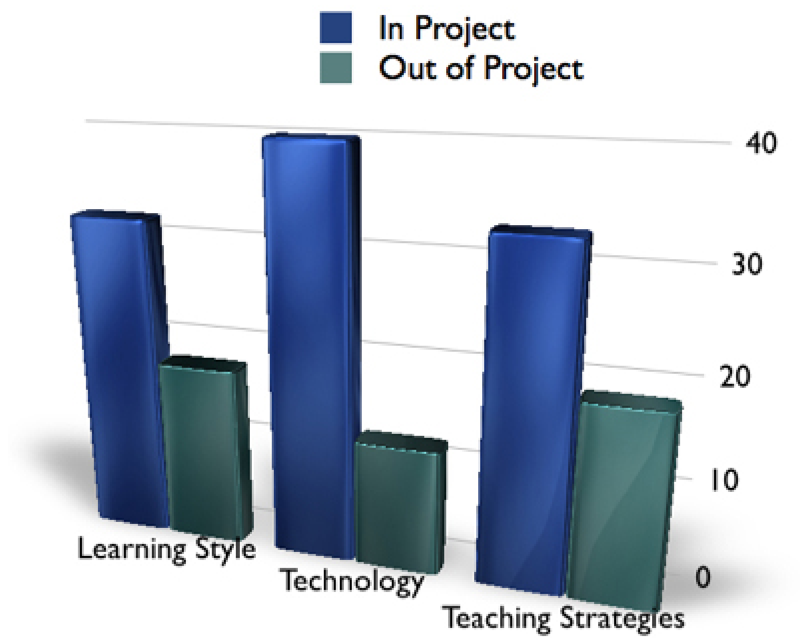

Figure 5. Students' report of whether teachers in and out of the project were teaching in ways which (a) met their learning style, (b) used technology expertly, or (c) used teaching strategies that helped them learn better.

Students' Response to Technological and Pedagogical Shifts

Students' Achievement Indicates More Project Students Than Nonproject Students Were Able to Succeed With Technological and Pedagogical Classroom Shifts. No educational innovation in the state of New York would be recognized as valid without reference to impact on Regents scores. Though this middle school's students achieve at high levels relative to the rest of the state of New York, students in the project classrooms showed increased achievement across the board where curriculum areas were targeted. More importantly, students reported specific ways technology assisted them in learning science concepts.

Earth science enrollment had historically been based on recommendations from previous science teachers. If students were struggling, they were quickly advised to enroll in an alternative course with a less rigorous schedule. The year of the project marked a shift in policy allowing students to freely enroll in New York Regent's Earth Science at the school. Students were free to choose the challenge level they wanted to set for themselves. Students could nominate themselves for the higher challenge in the more difficult course and, in fact, they did. Earth science enrollment increased more than 42% for this school year.

With this policy change and associated increase in enrollment, the science department chair anticipated more than a few calls from concerned parents about the difficulty level in the classroom. What she found surprised her. With the introduction of MacBooks, probeware, iLife applications, and new teaching strategies, students spent even more time in her class, and substantially more students achieved the highest level of success in this rigorous course. Furthermore, 100% of testers scored in the top two testing brackets (scoring 65 to 100%), and while increased numbers of students dropping the class were anticipated, no students resigned the class during the school year. The New York State scores improved for physical science students, as well, at the middle school.

The data revealed that 91% of the students scored a 3 or 4 the New York State eighth-grade science assessment, with no infusion of technology in the year prior to the project. Excluding the mainstreamed special education students (commonly referred to as 12:1 students because of school educational policy), this score remained high at 96%. The year of the technology infusion 94% of all eighth-grade students within the school achieved a score of 3 or 4. Excluding the 12:1 student scores, this score would be 99% (see Table 1).

Table 1
Three-Year Performance Trends for All Eighth-Grade Science Students at the Target Middle School (New York Regents, 2008)

Grade 8 Performance Levels - All Students

Number of Assessments as values		2007-08	2006-07	2005-06
Grade 8 Sci: Scale	Level 1	2	4	2
	Level 2	15	22	27
	Level 3	97	151	168
	Level 4	133	124	108
	Students Tested	247	301	305
	% at Level 1	1%	1%	1%
	% at Level 2	6%	7%	9%
	% at Level 3	39%	50%	55%
	% at Level 4	54%	41%	35%
	% at Levels 3 and 4	93%	91%	90%

Regents SCIENCE Performance Levels - All Students

Number of Assessments		2007-08	2006-07	2005-06
	Scored 0 - 54%	0	0	0
	Scored 55 - 64%	0	0	0
Regents Phy Set/Earth Sci - Jun	Scored 65 - 84%	14	7	5
	Scored 85 - 100%	143	103	115
	Students Tested	157	110	120
	% from 65 - 84	9%	6%	4%
	% from 85 - 100	91%	94%	96%
	Percent Passing (65 - 100%)	100%	100%	100%

To monitor incoming students' knowledge and experiences and examine the effect of teachers' planned integration of technology, pre- and postassessments were given for each unit taught. Students' performance on these assessments revealed large increases in student knowledge across the content area, as well as an increased growth from the previous years' performance. Figure 6 shows the scores and growth for students involved in the intervention, as reported per science topic in physical science.

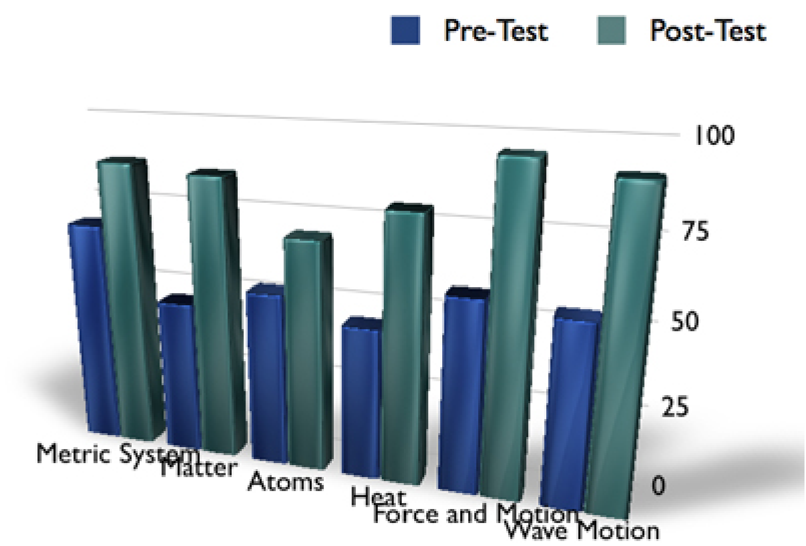

Figure 6. Students' pre and post test comparisons of project science students listed for each unit of study.

The number of students achieving the highest possible score of 4 (mastery level) went from 41% in 2007 to 54% in 2008, increasing numbers of students achieving perfect mastery by 31%. This statistic is even more impressive when viewed in light of the fact that substantially more students elected to enroll in earth science, changing the demographic of students in the physical science course. Yet, the high levels of achievement were not only maintained, but actually increased with the infusion of technology into the course. Figure 7 illustrates the students' achievement on the mandated New York Science Test for the physical science teachers participating in the project when compared to their students' prior year achievement.

Overall, student achievement remained high or improved for all science units taught in the classrooms of the project teachers. When asked how they could take the extra time required to complete the technology projects they required of their students and still cover the same amount of curriculum, they admittedly said they had done far less review than in years past. One teacher estimated the amount of classroom instruction time forfeited from direct instruction in the prior year was approximately 5 weeks. Despite the urge to succumb to the pressures of other teachers to "keep up," they incorporated more constructivist pedagogies, implemented technologically enhanced lessons, and still were pleased with their students' performance at the end of the year.

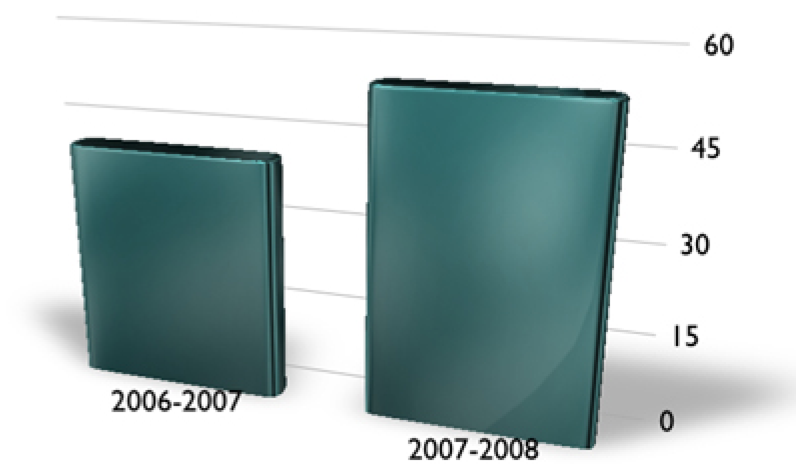

Figure 7. Physical science scores for students of project teachers for the year prior and the implementation year.

Students Identify Technology Among Attributes for Best Learning Environment for Science. Students participated in a two-tiered interview process in which the foci were intentionally separate (see Appendix C). Knowing that our presence at the school would be associated to the technology we donated and the lessons we helped teachers facilitate, we asked students specifically to talk about lessons that they learned the most from throughout the year.

Technology was not brought up by the interviewer in focus groups or in individual interviews until the second tier. Whenever students brought up technology in the first part of the interview, they were redirected to speak directly about how the lesson helped them learn better. Regardless of the interview structure and redirecting, students were eager to share about the technology and its impact on their learning. An example of how students responded follows:

Interviewer: Can you tell me about a lesson in science that you learned really, really well?

Jennifer: Most likely, the specific heat lab. We did a lab with that where we used the probes to see the heat of the water while boiling, and it was fun to do that even though we had to stir the whole time. It kind of hurt my arm. I think I learned a lot from that because you could remember all the graphs and stuff from the laptop. I did really well on that test still ...

Interviewer: So tell me about the parts of that lab that made it stick for you.

Jennifer: Well, in other labs, we sometimes don’t use the laptops and the technology, and I really like the technology, so I think I learn better and I remember it better when I use it. So it was easier for me to understand the whole concept of specific heat.

Jennifer recognized the tool as inherently allowing important repetition and activation of visual learning style. While there were many other, nontechnologically enhanced labs she experienced throughout the year, the student identified the lesson that evoked a specific technology that was most helpful for her. Similarly, Rebecca responded to a prompt about a science lesson where she learned the most:

Rebecca:	It was the heat transfer lab – where we melted ice and used the graph and showed how the ice changed from a solid to a liquid to a gas and the time it took to change it.
Interviewer:	Could you run me through the lab and tell me what you did?
Rebecca:	We put ice on this heater, and we plugged this probe into the computer, and we setup a graph program, and we stirred the ice, and the graph showed the change in heat over time.
Interviewer:	What about that lab stood out for you?
Rebecca:	Because you got to see what was actually going on – instead of having a teacher explain what was actually was happening.

Though the lab was different, the comments and recognition of the importance of technology to understanding were similar. Of the more than two dozen students interviewed, only one did not include a lesson that incorporated technology for a major portion of the lesson. The most commonly mentioned tools that helped students learn science were those tools providing live data that connected to the concepts the teacher was teaching.

One way students described science tools helping them learn better was through tools providing direct access to data that would otherwise be unattainable. These included data collecting probes, digital microscopes, and Web-based database access points for such data as live seismic and other global data. As seen in Figure 8 students reported a greater ease of collecting data, repeating experiments, and making data more precise.

Students also felt that time was saved in the lab experimentation and that it made concepts more clear when they used the technology than when they conducted labs without it. References to "real data" in the interviews were frequent. Students repeatedly said the visual nature of the tools helped to facilitate understanding. Students spoke directly to specific inquiry-based skills that reforms and standards currently promote for science students. These notations made by students to technologically enhanced lessons included the ability to repeat experiments, making data more precise, examining real-world data to solve problems, and making concepts more clear.

Another way in which technology was helpful to students learning was the opportunity to create artifacts that represented their understanding of the content covered in class. Making slideshows, creating books, and writing, shooting, and editing video were among those mentioned by students:

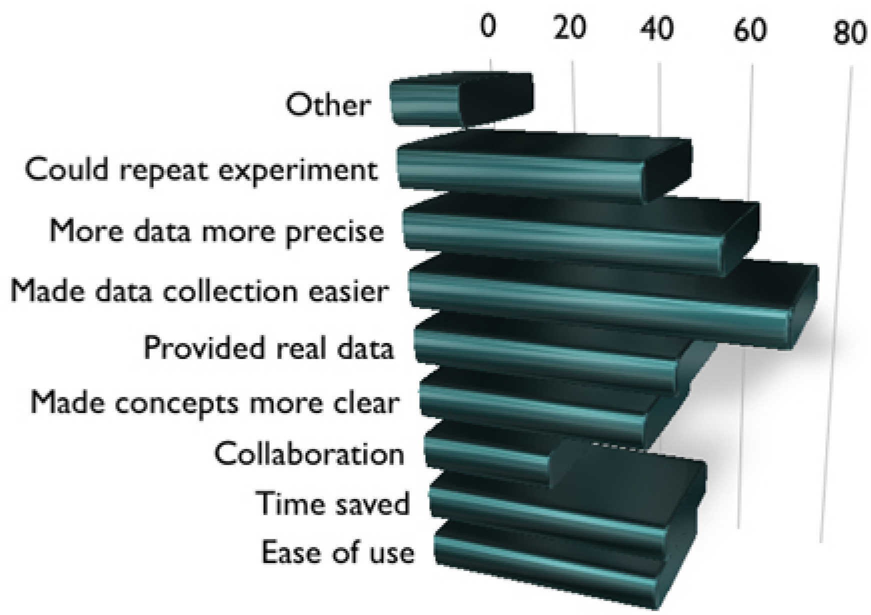

Figure 8. Student responses regarding how technology helps them learn science.

Britany: What worked really well was the iPhoto books that we used the Macbooks for, and it was a program that we used. We got to find information pictures and put it into the iPhoto book in our own way. We were constantly going over through the iPhoto book reviewing what we had written, so it kind of got stuck in our heads and we watched everyone else's iPhoto book, so that was a really good way of learning for us.

Interviewer: What is so different about this lesson that helped you?

Britany: In previous years we didn't use much technology. My science grade wasn't as great as it is in this class. Because you weren't as hands on, you weren't learning everything – you're just hearing them. When you do the labs and stuff – we didn't have the technology that we have to take pictures and to do – and so you got to see it in a different eye.

Britany enjoyed the ability to re-present information that had been discussed in class. During the lesson she was actively searching for images that would best demonstrate the geological concepts and helping the editor of their group make their presentation of the concept clear. Though less than a third of students pointed to collaboration as the technology's strength, Britany enjoyed the lessons more as a direct result of being able to work with others and present her ideas. Britany was a socially oriented learner and, like many girls in science, enjoyed working together to learn. She also enjoyed the collaborative sharing from other groups and indicated from her own perspective that it was a powerful way to help her and others learn.

When students were asked specifically about lessons that helped them learn well, they almost unanimously named lessons that incorporated technology. Though these activities were revised lessons from the teachers' standard repertoire, the lessons were recognized for their ability to improve students' ability to learn. It is noteworthy to consider that no student responded in any way similar to "lecture more to me, please," though the most widely used strategy for this school is lecture, book chapters, and paper pencil packets. Clearly, changing strategies and tools made a difference to these students. Students recognized not only the difference in the tools used but also recognized that teachers were employing different teaching strategies.

Throughout the year students were asked to report on how the tools used in their science classes helped them learn. The green and blue areas of Figure 9 represent the more than 80% of the students who were satisfied or very satisfied with the choice of technology tools teachers chose to integrate in their lessons. Not only did students report that the use of tools was helpful, they reported enjoying science more in project teachers' classes, as well.

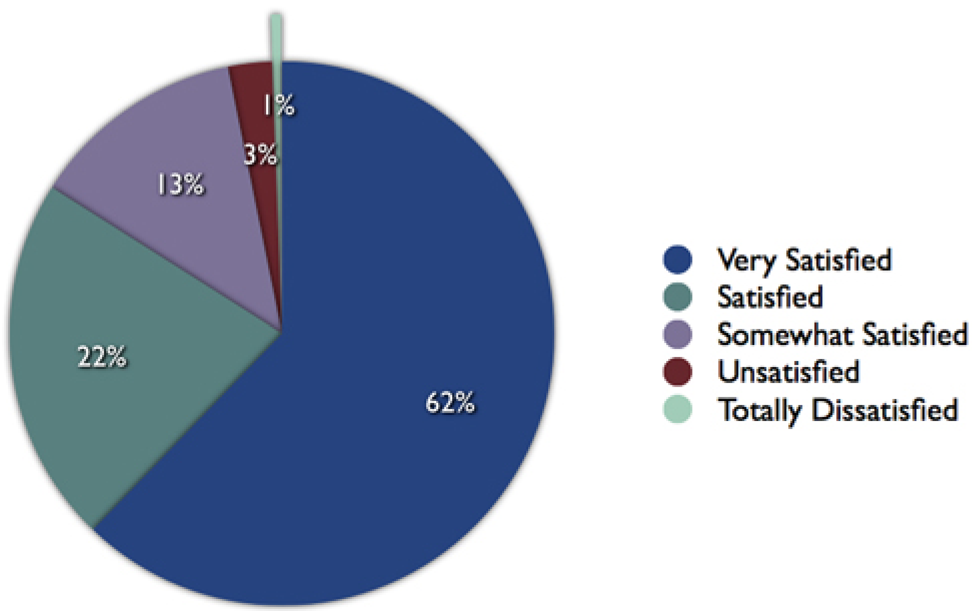

Figure 9. Reported student satisfaction with project teachers' use of technology for teaching science.

A statistically significant difference was found in the reported amount of student enjoyment of class work (t_{719} = 2.314, p = 0.021, d = 2.31) with students in classes taught by project teachers reporting more enjoyment. Though this finding can be attributed to personality traits of the individual teachers and perhaps even their disposition for trying to meet the needs of children, there was a correlation between teachers who chose to be engaged in the project all year long and the positive responses of their students to the ways science was being taught. Students felt that the technology had helped them to learn, and none of them, after an entire academic year of implementation, cited an instance where technology was not helpful.

Sometimes teachers indicate that unreliable equipment, troubleshooting, and uncertainty are reasons not to try technology (Pedersen & Yerrick, 2000; Odum et al., 2002). We asked students if there was a time when their teachers used the technology and it got in the way of what they learned. The response was an emphatic "No." Students found ways to get around any problems or uncertainty that arose during lessons. No students found technology to be a hindrance to their learning. None mentioned any difficulties in learning or implementing technology.

There were times when the technology presented problems. Printers did not work, probes were broken, cameras forgotten, and draft papers lost because of computer crashes. However, students tended to cite instances where the tools allowed for collaboration. If trouble arose with the technology, students came together to find a solution.

Brenda:	First you had to do the researching, which kind of started our information and what we were doing and what it was all about. Then we worked as a group to explain what iPhoto book was, and that was pretty fun because everyone loves using the Macs, and we got to work in groups and everybody loves that. Then we started putting pictures in, and we got to take pictures of it all, so if there was a rock or mineral it was in we got to use the probeware and take pictures of it all so, so we pretty much went through all the steps like that.... We're in the same class, so we have the same questions. We all learn the same thing, so they know exactly what you know. If you need help with something, they're there. And we work in groups a lot, so we help each other – we piggy back off each other, so.
Interviewer:	The groups that you are in – have you been in groups with these people in other classes as well?
Brenda:	Not really.

The students believed that their needs were met through technology integration and through the use of pedgagogical strategies that would be impossible otherwise. The teachers involved in this project were able to activate learning styles and address the needs of their students while maintaining student motivation and interest. Students not only liked the technological tools being used, but they also recognized that these tools helped them to learn and succeed.

Interviewer:	Do you think without the use of technology that that lesson would have had the same impact on you?
Britany:	No. I think it would have had a completely different impact without. It would be much harder, and it would be a lot harder to understand and comprehend what was supposed to be happening.

Not only did students strongly believe that the teacher using technology helped address their individual learning styles, they also felt that what their teacher had accomplished would be unlikely without employing the technology.

Learning and using the new equipment was never viewed as a hindrance to learning, but instead as an opportunity. Students collaborated to teach and learn the technology, without interfering in their learning. The collaboration, developed through the science class, allowed the students to act as experts. It provided the opportunity to learn through interactions with their classmates and directly addressed interpersonal, social learners.

Discussion and Implication

Technology has been shown to help students learn in ways that are connected to their learning styles where traditional methods have failed (Ballone & Czerniak, 2001; Cafferty,1981; MacMurren, 1985; McLoughlin, 1999; Pizzo, 1981). In light of these and other findings, we sought to answer the questions of how specific tools and pedagogical strategies used by teachers were interpreted by their students. Although the professional development was open to all teachers at the middle school, the self-selection of science department faculty not using technology offered a unique opportunity to conduct a yearlong examination of how teachers' efforts to use technology benefited science students without us having to decide how to create a control group to deprive students of the tools we thought were best for children.

Many teachers chose not to use the available technology, but teachers remaining in the project for the duration of the year noted that students were not only more engaged and more motivated, but also better able to assimilate what teachers taught because of the way each learned best. In some cases students were adamant about the differential impact of technology-rich environments on their learning, addressing the importance kinesthetic, hands-on learning and visual learning.

The project students mentioned during the interview not only the tools used, but also the concepts being taught with the tools. Examination of surveys and interviews revealed detailed descriptions of how the tools used improved the teaching effectiveness for this particular group of students. Teachers reported increased student enjoyment of the tasks of learning science while giving examples of what helped and why.

Teachers responded that they spent less time covering content and still enjoyed the success of high achievement of their students— leading them to believe that less stress imposed on covering and reviewing material repeatedly for standardized achievement tests may be a flawed approach with minimal returns for the stress invested. Additionally, data suggests from the earth science student achievement that more traditional and challenging curriculum may be more accessible than school historical practices have maintained. This was evident when policy changes opening up earth science to any student still resulted in 100% student success when supplemented by technology and inquiry strategies. It may very well be that more students may actually be able to achieve the highest level of science performance if appropriate technology and revised pedagogy replaces a traditional repertoire.

Students reported through surveys and interviews that teachers' new strategies actually connected better with their needs, which were previously neglected by a heavy emphasis on lecture and text-based teaching strategies. Future studies will help make the connection between specific learning styles, tools, and teaching strategies more explicit. Possibly, teachers who self-select projects like these impact our findings, but it seems clear that students learned specific science concepts in the studied classroom environments where technology access was improved and teaching strategies were adapted to this new learning environment.

However, not only are we arguing that students found their teachers to be more effective, teachers themselves also reported renewed vigor in their teaching, and their scores improved from their prior years' successes. Teachers compared their own students' achievement to those of past years and saw improvement as well and noted comments from students informing them about important changes they had observed that would not have happened in the former poorly equipped environment.

Finally, further studies documenting the achievement gains due to technology implementation will further help to garner support for such programs to be implemented in the future. Such studies will enrich the conversations of those technology proponents who advocate that technology implementation in and of itself is a solution. Excellent teaching can be enhanced with thoughtful consideration for the tools employed, and future studies will confirm what many students and teachers reported here—that some science learning opportunities are likely not possible without the use of technological tools.

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Appendix A

Example Question from the Learning Environment Inventory (Fraser, 1982).

1. Members of the class do favors for one another.
2. The class has students with many different interests.
3. Students who break the rule are penalized.
4. The pace of the class is rushed.
5. The books and equipment students need or want are easily available to them in the classroom.

6. There is constant bickering among class members.
7. The class knows exactly what it has to get done.
8. The better students' questions are more sympathetically answered than those of the average students.
9. The work of the class is difficult.
10. Failure of the class would mean little to individual members.

11. Class decisions tend to be made by all the students.
12. Certain students work only with their close friends.
13. The students enjoy their class work.
14. There are long periods during which the class does nothing.
15. Most students want their work to be better than their friends' work.

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Appendix B

Interview Protocols

Interview Protocol Tier #1

First Tier Questions: Teaching and Learning (Without mention of technology)

- Can you please tell me your name, your science teacher, and what period you have science?
- How do you like to be taught in your science classes? What type of learner are you? What are your strengths as a student?
- Can you tell me about a science lesson where you learned something really well? What made it such a good lesson?
- How would you describe a normal science lesson?
- What does your teacher do to help you learn in science class? Can you compare your current science teacher with science teachers you have had in the past? What is the most important attribute of a teacher that helps you learn?
- Can you think of a science lesson that did not go well? Can you describe it for me? Why do you think this lesson didn't go well?
- What would you have done differently to improve this lesson for students?
- If you were a science teacher, how would you go about teaching your class? What strategies would you use? What tools if any would you need to teach your class?
- How is your learning measured in school? Do you think this is the best way to measure your learning? Can you think of other ways that your learning can be measured?

Interview Protocol Tier #2

Second Tier: (Referencing Technology Use in Teaching Science)

- How do you use technology at home, outside of school?
- How often would you say you use technology outside of the classroom?
- How do you use technology in your science class?
- How often do you use technology in science?
- Does technology help you to learn science?
- Can you think of a specific lesson where your teacher used technology?
- How was it used? If it was helpful, how did it help you?
- What about it did you like or dislike?

Appendix C

Learning Styles Inventory

In order to familiarize students with the notion of learning styles and discussion of their own strengths, students were given a website to examine their own habits and learning attributes. After they had completed their self-inventory, they were asked to participate in the survey where they were asked how teachers were teaching in ways that addressed their particular needs as learners and styles of learning that best suited them. This is an interactive worksheet which produces a wheel based upon multiple intelligences and learning styles. Jean Maund is credited with the development and publication of this questionnaire.

Website:
http://www.bgfl.org/bgfl/custom/resources_ftp/client_ftp/ks3/ict/multiple_int/questions/choose_lang.cfm

Some sample questions asked with responses ranging from:

This is not like me at all	I am very rarely like this	This is a bit like me	This is sometimes like me	I am always like this

1. I am an independent thinker. I know my own mind.

2. I can picture scenes in my head when I remember things.

3. I always do things one-step at a time.

4. I enjoy being outdoors when I learn.

5. I am interested in why people do the things they do.

6. I like working and thinking on my own and quietly.

7. I remember things like telephone numbers by repeating them to a rhythm.

8. I am observant. I often see things that others miss.

9. I learn best when I have to get up and do it for myself.

10. I can recognize and name different types of birds, trees and plants.

11. I enjoy writing things down.

12. I know myself well.

13. I can link things together and pick out patterns easily.

14. I get restless easily.

15. I can pick out different instruments when I listen to a piece of music.

16. I am good at mathematical problems and using numbers.

17. I like to work with a team.

18. I can remember pieces of music easily.

19. I learn well from listening to others.

20. I enjoy social events like parties.

21. I enjoy games involving other people.

22. I enjoy working on my own.

23. I find it easy to explain to others.

24. I enjoy logic problems and puzzles.

25. I can take things apart and put them back together easily.

26. I like to think through problems while I walk or run.

27. I like to use charts and diagrams in my learning.

28. I like to think out loud.

29. I need to see something in it for me before I want to learn something.

30. I can sort out arguments between friends.

31. I like to make lists.

32. I keep or like pets.

33. I have a good sense of direction.

34. Pollution makes me angry.

35. I can use lots of different words to express myself.

36. I have a good sense of balance and like to move around a lot.

37. I am sensitive to the moods and feelings of others.

38. I like to work with my hands.

39. My mood changes when I listen to music.

40. I enjoy making music.

Example Output from 100+ questionnaire: