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Digital Microscopes: Enhancing Collaboration and Engagement in Science Classrooms with Information Technologies

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Abstract

This article describes the implementation of laptop computers and digital, USB-based microscopes (Proscopes®) in science classes. This technology integration project took place in a rural school district in North Carolina. This school is in a low socio-economic area, with an approximately 60/40 ratio of Caucasian to non-Caucasian students. Additionally, this school has had a comparably low level of access to technology for students and teachers. Traditional science tools (light microscopes) were replaced with four sets of a laptops with ProScopes as technology-enhanced collaborative work areas. With minimal formal technical training, students adapted and used these technologies to examine and explore content in cellular biology and to create electronic lab reports using digital images and motion videos captured during activities. The infusion of technologies in this instructional environment transformed the learning experiences through the powerful combination of science and technology, resulting in enhanced student processes and products.

Research and history chronicle how science and technology are inextricably bound in both academic settings and throughout the natural world (American Association for the Advancement of Science [AAAS], 1989, 1993; National Research Council [NRC], 1996). Science and technology educators teach of the hybridization of technology and science. Research suggests that differentiating science from technology is becoming increasingly difficult (AAAS, 1993), and the two disciplines have become interwoven on many levels. The *National Science Education Standards* state, "The relation of science to technology should be part of [students'] education" (NRC, 1996, p. 20).

However, there are times when these disciplines are purposefully separated in public education classrooms. Too often, science is taught to students in K-12 science classrooms without exposure, access, and experience with the complementary technology tools. In US K-12 school systems, technology is often taught in computer labs without a context or clear connection to its relationship with other disciplines.

The research described in this paper examined the process of teaching and learning both science and technology within the same classroom. The paper discusses the process of integrating technology in science classrooms and how it was a catalyst for change in the way students experienced content and produced deliverables such as laboratory reports.

Previous Research

Linking Science Reform Efforts With Technology Integration

The science education community emphasizes the implementation of inquiry-based instruction in both primary and secondary schools. Reform-driven publications in science education emphasize the importance of inquiry both as an instructional method and as a learning framework (AAAS, 1989, 1993, 1998; National Research Council, 1996). Teaching science via inquiry involves engaging students in the kinds of processes used by scientists. These processes include asking questions, making hypotheses, designing investigations, grappling with data, drawing inferences, redesigning investigations, and building and revising theories (Kubasko, Jones, Tretter, & Andre, 2007).

Science, Technology and Student Engagement

Science and technology are often used together. Hennessy, Deaney, and Ruthren (2006) discussed ways teachers make use of computer-based technologies to support the learning of science. This study suggested that technology supports stepwise knowledge building and application. Such applications have implications for both curriculum-related science activities and emerging computer-based learning technologies. Technology helps students construct links between theories and phenomena by extending the human capacity.

Chi-Yan and Treagust (2004) suggested that biology educators are increasingly using technology to supplement their teaching. A variety of computer technologies have been used over the past two decades to enhance student learning of many of the biological sciences in colleges and universities. Computer technology and educational software has provided new learning opportunities that can change the look and feel of traditional science classrooms. This does not necessarily imply that learning in traditional education is ineffective. However, traditional methods sometimes fail to reflect skills and interests of students who have grown up in the digital age. Technology can enhance learning environments and increase opportunities for authentic hands-on experiences (Zumbach, Schmitt, Reimann, & Starkloff, 2006). Computer technologies support the development and implementation of teaching and learning strategies that support many important science skills (Maor & Fraser, 1996).

According to Schoenfeld-Tacher, Jones, and Persichitte (2001), technology and multimedia facilitates the knowledge-construction process for students by allowing learners to construct links among their prior knowledge and the new concepts. This assertion supports research suggesting that science education should include both constructivist methodologies and technology integration as a natural part of its ideology.

The limitations of the light microscope have been the focus of several research studies. Computerized magnification systems and video-based virtual experiences have been studied in the attempt to improve areas such as the ease of viewing, interactivity, and improvement of group learning activities within the context of science education. Downing (1995) noted the size of the ocular as an inhibitor to communication and other dynamics within group learning situations and suggested the use of magnified images on video screens.

In the Harris et al. (2001) study of the replacement of light and stereo microscopes with a virtual imaging system, digital virtual experiences largely occurred in science coursework at the university level, with emphasis on potential in the medical and biomedical fields. Dee, Lehman, Consoer, Leaven, and Cohen, (2003) stated that a comparison of virtual slides to traditional microscopy demonstrated that information technologies improved the identification of cellular structures by learners. Further information from the study indicates that the quality of the digital images is often superior to other formats.

“Show and Tell” Teaching

The science teacher involved in this project felt encumbered and unequipped by the lack of technology at her disposal, thereby resulting in a high quantity of “lecture and listen” instructional scenarios. The stand-and-deliver method is often referred to as the expository approach to instruction, in which the teacher spends most of the time giving verbal explanations while the students listen and write notes. According to Wekesa, Kibose, and Ndirango (2006), inadequate and limited teaching methods tend to negatively affect the learners’ knowledge and dispositions of scientific concepts and associated methods.

Schönborn and Anderson (2006) suggested that a large number of static and dynamic multimedia technologies exist and are available to the science education arena. However, due to inadequate funding and other laboratory or resource restraints, teachers must often employ the “show-and-tell” approach in their classes, using outdated materials that may be inadequate in nature or quantity. This often forces students into a passive or receptive role in the science classroom. Linn (1998) suggested that students will acquire knowledge in such situations, but it will be mostly fragmentary, not integrated into a larger mental model characteristic of hands-on learning.

Participants and Setting

This project took place in biology classes of a rural school district in southeast North Carolina. This district is primarily in a low socioeconomic area, with an approximately 60/40 ratio of Caucasian and non-Caucasian students. The schools were chosen due to geographical location, diversity in student population, and limited access to appropriate technology. Fifty-five students across three classes were observed for this study.

The North Carolina science curriculum deals with understanding cellular biology through microscopy applications. As stated in the North Carolina Standard Course of Study Competency Goal 2, “The learner will develop an understanding of the physical, chemical and cellular basis of life” (North Carolina Department of Public Instruction, 2004). This area of the curriculum provided an excellent opportunity to infuse the digital microscopes in order to both benefit the students and provide a suitable avenue for the observational research needed for this endeavor.

The classes selected for the project were based on convenience and willingness of the teachers to integrate technology in their teaching of microscopy and cellular biology. There are obvious limitations in research conducted with the use of convenience samples and populations. However, the integration and substitution of newer technologies applied in this research setting was a purposeful and calculated response designed for the teachers, students, and content area within this district. Perhaps most importantly, the setting (underequipped science education classes) can be widely generalized to science education classes in settings across the U.S. and many other countries throughout the world.

After analyzing the science curriculum, meeting with the teacher, and observing selected classes, the researchers determined that there was a need, an interest, and a willingness to embrace and field test the integration of new technologies despite the lack of technology within the school. This environment appeared to be a natural fit to explore emerging technologies and their effects on students' performance and products.

Focus Questions

The primary interests in this project were to determine the following:

- How can information technologies be effectively integrated in the process of teaching and learning microscopy and cellular biology?
- In technology-poor school environments, what are the consequences of replacing/substituting traditional equipment and educational methodologies with technology-rich tools and approaches?

Conditions Prior to Technology Integration

The classroom conditions were centered around traditional light microscopes being used with teacher-led instruction. The light microscopes were aged, heavy, and had obvious signs of wear and tear due to many years of student use. Some showed signs of age and use such as low luminescence scratched lenses, and limited field of view. The teacher had been told that the schools could not afford replacements and the teachers had to do "the best" with what they had in their classrooms.

The instructional conditions consisted of teachers providing lectures on science content, then allowing the students the opportunity to "take turns" in small groups looking at samples of cells through the light microscopes. Only one student could look through the eyepiece of the traditional microscope at a time, and there was little reliability as to what was seen due to the single eyepiece design. After looking at samples, the students would sketch and diagram on a paper handout what they had seen. Afterwards, students were asked to make a poster using their handwritten lab reports and sketches.

Prior to the treatment teachers welcomed technology tools and were willing to participate in technology integration, with the hope of improving student learning, but had few due to school conditions.

Through interviews with teachers and analysis of the situation the researchers were able to identify the following problems:

- The available technology was hindering the instructional design and delivery.
- There was a disconnect between students learning technology and students using technology as a tool to learn science.
- Student work products did not incorporate 21st-century technology skills.



Figure 1. Images of Vernier ProScope®. Left image retrieved with permission from Vernier Web site (<http://www.vernier.com/labequipment/proscope.html>).

Action

Using several areas of justification for use of microcomputer based technologies discussed by Leonard (1992), the researchers selected the Vernier ProScope digital microscope kits for implementation in several local science classrooms (Figure 1). These areas of justification would serve as a guide in the adoption and analysis of these tools and their overall usefulness in the technology integration process. Areas for consideration included

- Economic use of laboratory facilities and materials.
- More efficient use of instructional time.
- Increased interactivity.
- Ability of the technology to provide more concrete representations of abstract concepts.
- The ability to interact with phenomena characteristic of a science classroom.

When connected to a microcomputer, these units replaced the use of standard light/electric microscopes frequently found in science classrooms. Four microscopes were purchased with grant funding. These units were used with four existing laptops, which were accessible for use by the researchers via the sponsoring university of employment. As a point of clarification, the laptops used in this project were 4 years old and could be described as “average” laptops with configurations common to most consumer-grade laptops running Microsoft Windows and Microsoft Office in the condition of laptops of this approximate age.

Prior to the digital microscope technology integration, students were observed receiving instruction on science content and using traditional microscopes with prepared slides. After observing samples using traditional microscopes, students were asked to produce a written lab report with diagrams individually drawn from their memory of images seen through the eyepiece. Students completed laboratory reports describing their learning experience using the tools that were available – pencils, paper, and poster board while using handwritten reports and sketches.

The process of integrating the technologies (laptops and ProScopes) as a replacement for the traditional tools was straightforward. After discussing and planning sessions with the teachers, the researchers brought the laptops and digital microscopes into the classrooms during sessions when the students would have normally used traditional light/electric microscopes. The researchers substituted the traditional microscopes for the laptops and ProScopes (see Figure 2), creating microcomputer workstations where students would work as a team. The technologies were used in three different 90-minute classes.



Figure 2. Example of workstation and close-up of computer screen.

During the technology integration sessions, the students received a brief lecture on science content focused around what they would be seeing in their field samples. The students were given less than 5 minutes of instructions concerning the digital microscopes and associated operating directions. Next, the students were asked to observe field samples (pond water, tree bark, tissue samples, etc.) in a small dish using the digital microscopes. During these observations, the students were asked to investigate each sample, but because they were using the digital microscopes and the laptops, they would not individually observe the samples with “one set of eyes at a time” as they would when using traditional microscopes. Integrating the digital microscopes allowed for teams of students to visually examine each of the samples (see Figure 3).



Figure 3. *Students examining sample with ProScope during laboratory activity.*

Beyond working together to examine field samples using the digital microscopes, students were asked to use the software on the laptop computers to take digital still and motion images of the observed samples (see Figure 4). This added ProScope feature promoted students' interactions with the samples through using the technology in a hands-on manner, as opposed to observing only. Students discussed what they were seeing on the computer screens with their classmates and took digital images when they saw exemplary examples. The researchers and teacher would walk around the room, giving appropriate guidance where needed.

After they worked together to analyze the field samples, students were asked to develop lab reports using the digital images they had collected. The images were saved and stored on the laptops. The students were asked to use the same laptops they used with the digital microscopes during the examination of the samples and to complete the laboratory reports electronically using Microsoft PowerPoint. Afterwards, the students presented their reports along with their electronic “evidences” in the form of digital stills and motion videos captured throughout their lab event in the form of a group PowerPoint presentation. The technology connected the observations of field samples to the lab reports as each group of students used the same computer to do both parts of the assignment.

Surprisingly, a minimal amount of training was needed for computer hardware and software operations. Students were given “just-in-time” assistance on an as-needed basis while they used the Proscopes and created their presentations. The lack of formal instruction was purposeful, allowing the teachers and researchers to observe the students as they used the equipment either through intuition or through prior exposure or experience. With little assistance, the students took the laboratory results and focused on

using PowerPoint to begin creating their reports and presentations. As explained earlier, one brief session of technical training per student group was provided. Without exception, the students were able to manipulate the digital microscopes, manage their files, and create their multimedia presentations – all in a group collaborative.



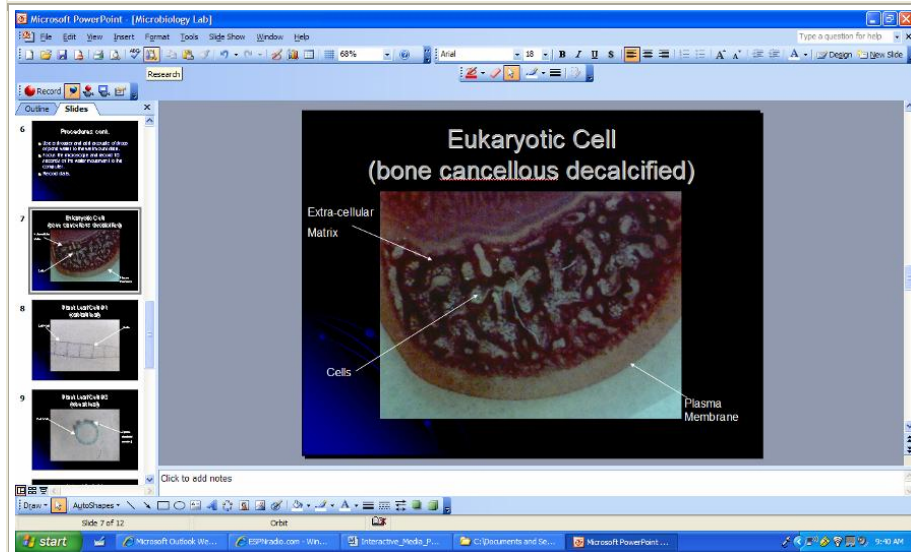
Magnified cell sample captured by student using digital microscope: Example 1



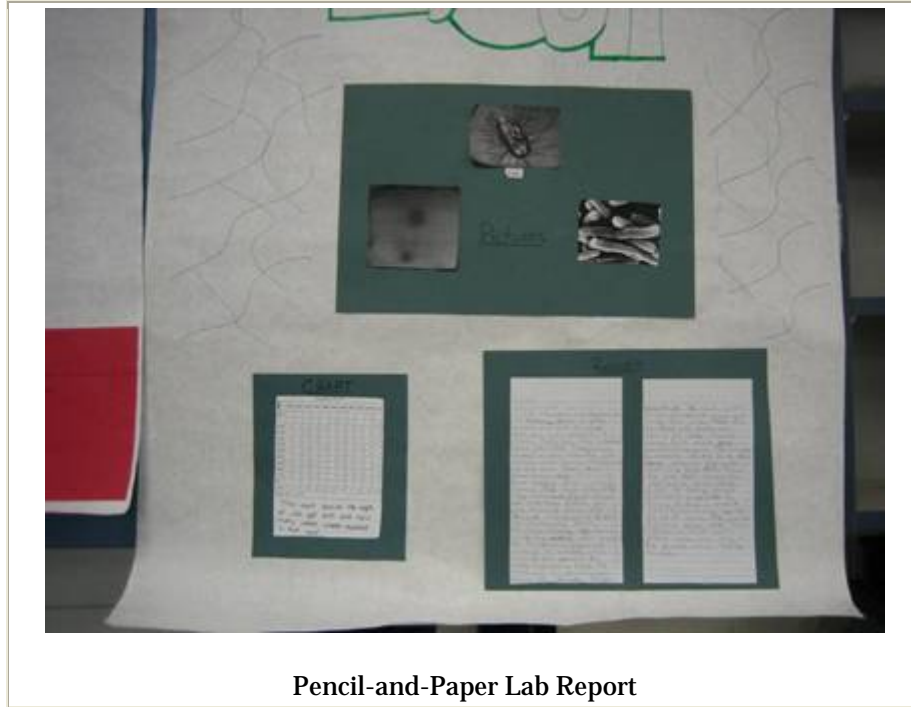
Magnified cell sample captured by student using digital microscope: Example 2

Figure 4. *Digital images taken by students.*

Students developed their electronic laboratory report (PowerPoint presentation) and had little/no problem importing saved images or motion videos captured with the ProScope onto the computers. The electronic reports yielded projects that appeared markedly different from the paper-and-pencil reports created by the same students when they did not have access to the technologies.



Digital Lab Report



Pencil-and-Paper Lab Report

Figure 5. Examples of two student lab reports: Traditional and technology enhanced (same group of students using different tools).

Figure 5 shows examples of work products from the same class of students, both with and without the use of the laptops and digital microscopes. These examples were typical of the differences in work products observed by the researchers and the teachers throughout all of sessions in which the information technologies were used in place of the traditional equipment. After each group of students was given the opportunity to create electronic lab reports, their work was saved by the teacher on a removable flash drive for display on the teacher station computer, which was connected to an overhead projection system.

Reflections

There have been many studies focusing on the attempt to measure the impact of technology on student achievement. In doing so, it is important to discuss several ways in which achievement can be described. It is popular (and often accurate) to measure the “success” of technology integration by how well students learn specific content. This is usually a process of taking two similar groups, pretesting content knowledge, integrating technology with one group, then posttesting content knowledge. Inferences must be made about the helpful, diminutive, or even harmful effects of technology integration in an instructional situation. Not surprisingly, most of the studies reported higher achievements and better attitudes toward science as a result of computer technology integration (Dori & Bamea, 1997).

However, there have been unexpected results, such as the Dawson, Skinner, and Zeitlin, (2003) study suggesting that technology integration possibly had a negative influence on the learning environment. Escalada and Zollman (1997) demonstrated in their study the effects on student learning and attitudes of using interactive digital video in the physics classroom, showing that interactive video materials are appropriate for the activity-based environment used in the course on concepts of physics. Such studies further support the idea that technology has the potential to enable science educators to effectively explore and conduct activities that incorporate technologies to introduce active learning processes into their classroom.

Leonard (1992) discussed areas of consideration for the use of computer-based technology in science education. Several of these areas germane to our observations included (a) economic use of laboratory facilities and materials; (b) more efficient use of instructional time; (c) increased interactivity; (d) ability of the technology to provide more concrete representations of abstract concepts; and (e) the ability to interact with phenomena characteristic of a science classroom. These areas provided a basis for analysis in determining the success of this project.

Interactivity and Collaboration

The researchers attempted to understand how the use of new technologies could be effectively integrated into cellular biology and microscopy lessons. The review of literature suggested that successful technology integration in science education often includes opportunities for increased hands-on activities, collaboration, and interactivity among the technology and the learners. Keeping this in mind, the researchers and teacher decided to use the naturally collaborative setting of the digital microscope and laptop as an opportunity to redesign the field sample analysis into a more collaborative activity than has been traditionally conceived. Interactivity via group-analysis was heightened by having students use the software associated with the digital microscopes to capture digital still and motion video of their observations. Collaboration was improved by having the students work in teams during the development of their electronic lab reports.

Change in Process, Change in Product

The researchers found several major implications resulting from integrating digital microscopes and laptops into the lesson. Having observed the same lesson without the use of these technologies, the lessons now appeared to come “alive” with activity and student engagement. Students were observed to be enthusiastic about getting to use the new technologies. Comments from students to the teachers included

- “Can we use these microscopes again next class?”
- “Let me show you the movie I made of the organisms moving across the screen!”
- “Can I bring in some other field samples to see what they look like too?”

These quotes from the students to the teachers are indicative of the engagement and excitement generated by the use of these technologies. Students were engaged in critical discussions about the cellular content. These technologies created an active learning environment uncharacteristic of the traditional scenarios where students would be sitting quietly at their desks handwriting lab reports or sketching pictures of cells with a pencil. There was also a degree of modernization with the electronic products prepared by the students. The incorporation of 21st-century technology skills was evident in their work products. Without exception, the adaptability of students to the new technologies with little training was amazing to observe. These students created products that were more technologically sophisticated than their previous written paper-and-pencil products. Figure 6 displays other digital images captured by students.

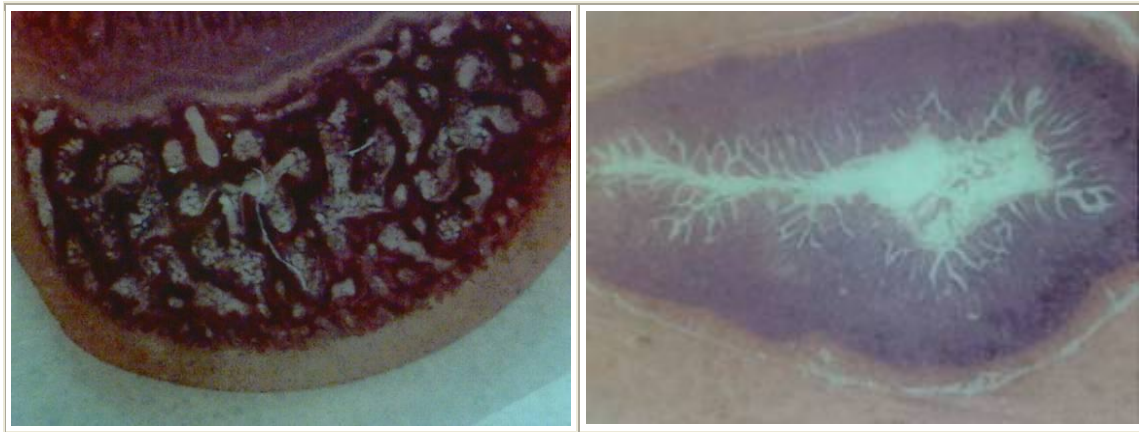


Figure 6. *Additional examples of digital images captured by students and used in electronic lab reports.*

After gaining access to the digital microscopes, the laptops and the associated software for capturing images, students exhibited diverse skills and abilities in their use of information technologies. The speed and fluency of these students in the use of technology with minimal assistance and great excitement was staggering for the researchers. Even though many of these students were of low socioeconomic status and did not have computers in their classrooms or homes to use, their performance on this project was not impeded.

Economically, the combined cost of the digital microscopes and laptops were very reasonable – especially when the laptop could be used to perform a myriad of other academic endeavors. A digital microscope as used in this experiment with a suitable laptop could be obtained for less than \$1,000. Instructional time could be increased through a higher level of student engagement and time on task. Interactivity was observed during student collaboration via the ability to “co-analyze” and diagram the cellular characteristics found in the field samples while working with the microscopes in teams. The technology was not able to necessarily provide more concrete representations of cells, but it did provide a higher quality representation with the high quality digital displays of the cells on the laptop monitors. Lastly, by allowing students to capture digital stills and motion video of the cells and the organisms in the field samples, the newer technologies allowed the students to interact with phenomena characteristic of microscopy and cellular biology education curricula.

Conclusion

This project allowed the researchers to implement, observe, and describe the integration of modern technologies as they replaced older technologies within the context of science education. Observing technology enrich and transform the educational endeavor was a meaningful process for the researchers and classroom teachers. This project reflected how technology can positively alter the learning environment. As opposed to distracting, inhibiting, and confusing the user as many newer technologies do, the digital microscope is a technology that engages users. This technology affordably enhances opportunities in science education through interactions with digital images and multimedia in interesting ways. In future studies, we plan to replicate this project to further understand how the technologies can affect the level of student achievement. Additionally, we plan on experiments measuring the way these technologies compare with traditional science tools in content and knowledge acquisition.

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