RESEARCH ON LEARNING

Using Digital Photography to Supplement Learning of Biotechnology

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Abstract

The author used digital photography to supplement learning of biotechnology by students with a variety of learning styles and educational backgrounds. Because one approach would not be sufficient to reach all the students, digital photography was used to explain the techniques and results to the class instead of having to teach each student individually. To analyze the effectiveness of this teaching technique, the students' responses on various examination questions were analyzed.

Key Words: *Technology; digital photography; undergraduate; biotechnology; lab equipment; gel electrophoresis.*

Teaching methods have become more visual as technology has evolved over the years. It is no longer common to simply see professors writing on a blackboard. Instead, they use websites to present diagrams of different processes. Various schools have used some form of photography or imaging to teach their students. For example, a study conducted in a developmental biology class at Davidson College required the students to make a poster instead of writing a lab report. This task taught the students about imaging and how to verbally present scientific data (Watson & Lom, 2008). In an undergraduate program at the Dental School of the University of Wales, students still learned oral pathology by looking through the microscope, but this was supplemented by color pictures placed next to the microscope (Aldred et al., 1990). In the U.K., photographs were shown to medical students and health care professionals to stimulate small group discussions about various topics (Parsell et al., 1998). In another study, the effectiveness of computer-graphic color still images was compared with that of color transparencies (Sneiderman et al., 1992).

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All these techniques use technology and images to try to improve on teaching. Similarly, I used digital pictures to supplement traditional instruction in teaching students how to use micropipettes, how to balance a rotor in a centrifuge, and how to read settings on a polymerase chain reaction (PCR) machine. The students then had to apply what they had learned to different situations – for example, by drawing what a gel would look like, given specific band sizes.

I assessed the effectiveness of digital photography compared with more traditional methods by analyzing the results of students' exams, which included questions that were based on digital-photography instruction and others that were non-photography-based. The students were in two different classes, taught using the same techniques.

○ Methods

This study was conducted in two biotechnology classes at Clayton State University in Morrow, Georgia. The first class had 18 students and the second had 23 students. The average (± SE) overall GPA for the students in the first class was 2.95 ± 0.1, and that for the second class was 3.0 ± 0.12. These two sets of grades are not statistically different from each other as indicated by a t-test ($P = 0.753$). The distribution of the grades is shown in Figure 1. All the experiments performed in class were based on kits purchased from a well-known biotechnology supply house that is geared toward high school and college students.

○ Assessment

On the exams given during the semester, there were questions based on the use of digital photography and other questions that were not based on digital photography. The success of the students on both types of questions was analyzed, using data from all students in both classes. The digital-photography-based questions required the students to read micropipettes, know how to balance a centrifuge rotor, and know how to read settings on a PCR machine. They also required the students to

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use what they had learned to draw a picture of a gel under different circumstances and compare staining with ethidium bromide versus methylene blue. The questions that were not based on digital photography were more factual in nature. The exact questions used are shown in Table 1. Identical questions were asked in the two classes.

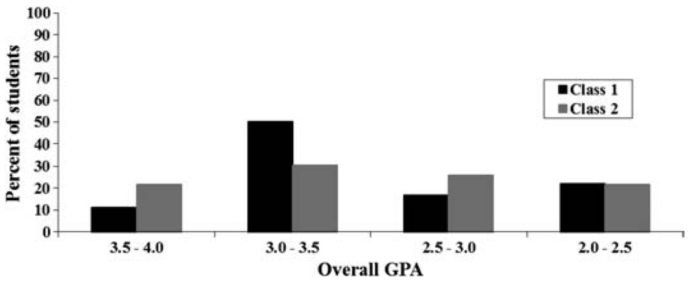

Figure 1. Overall GPA of students in the two classes. The percentage of students that had overall GPAs of 3.5–4.0, 3.0–3.5, 2.5–3.0, and 2.0–2.5 was determined.

○ Data & Statistical Analyses

The success of the students on the exam questions in both classes was analyzed. Each student was given a score of 100 if they got the question correct, or a score of zero if they got the question incorrect or partially incorrect. The graphs represent the mean ± SE. The standard error was determined from the number of students receiving a 100 or a zero.

Student's t-tests, analyses of variance (ANOVAs), and Tukey post hoc test comparisons were performed in Minitab. The significance of the data is indicated on the graphs (*$P < 0.05$, **$P < 0.001$).

○ Results

The grades for the students in the two classes are shown in Figure 1. As stated in the methods, the overall GPAs of the two classes were not significantly different. However, there are some differences between the distributions of the grades. The second class had a greater percentage of grades in the 3.5–4.0 and the 2.5–3.0 categories, whereas

Table 1. Questions asked on examinations.

Digital-Photography-Based Questions	Non-Digital-Photography-Based Questions
1. What is the volume on the p2 micropipette in front of you?	12. Identify a picture from the Internet or lab manual as an ethidium bromide stained gel.
2. What is the volume on the p20 micropipette in front of you?	13. Identify a picture from the Internet or lab manual as the apparatus used for protein electrophoresis.
3. What is the volume on the p100 micropipette in front of you?	14. Identify a picture from the Internet or lab manual as a protein gel.
4. What is the volume on the p1000 micropipette in front of you?	15. Identify a picture from the Internet or lab manual as a white light box used to view DNA and protein gels.
5. In this picture of a rotor, two of the six spaces have tubes in them. Where should a third tube be placed in order to balance the rotor?	16. What is the difference between log and semi-log graph paper?
6. On this picture of a PCR machine, state the temperature and time of annealing.	17. What are the steps in the Southern blot procedure and restriction fragment length polymorphism?
7. What is one advantage and one disadvantage of staining a gel with ethidium bromide compared to methylene blue?	18. What is a degenerate restriction enzyme site?
8. Given the distance migrated and size of molecular weight standards, draw a picture of what the gel would look like after performing electrophoresis.	19. Are primers used in PCR or Southern blot? Are probes used in PCR or Southern blot?
9. Given the data of the length of VNTRs (variable number of tandem repeats) from the mother and father, draw a picture of a gel.	20. What is reverse transcription?
10. Given a plasmid with restriction enzyme sites, draw what a gel would look like after cutting the DNA with restriction enzymes.	21. What are three features that all plasmids used in cloning have?
	22. Explain why the tube from the ligation experiment produced both blue and white colonies.
	23. The LacZ gene is always required to be part of the plasmids in order to perform the cloning procedure. True or false?
	24. Besides using blue/white selection, describe one other method for identifying your recombinant clones.

the first class had a greater percentage of grades in the 3.0–3.5 category. No statistics were performed on these data, because of the low number of students in each group.

Reading Micropipettes

Throughout the semester, in order to successfully perform the experiments, the students used micropipettes. Therefore, it was important that they acquired this skill early in the semester. Many students arrived at the class with little or no knowledge of how to use the different pieces of equipment. It would be difficult for the instructor to have all the students surround any piece of equipment in order to explain its use.

I set up an interactive webpage that displayed the different micropipettes set with different volumes. The students could click on a button that would show the correct volume. An example of this page is shown for a p2 and a p100 pipette (Figure 2). In order to assess whether the students were proficient in reading the volumes on the micropipettes, on the first exam, students went to a station and read the p2, p20, p100, and p1000 micropipettes that had been set at a specific volume. Overall, the students were successful in answering these questions (Figure 3), but there were some difficulties in reading the p100 pipette. An ANOVA test and Tukey post hoc comparisons showed that the p100 group was significantly different from the other groups ($P < 0.001$ when comparing the p100 to the p2, p20, and p1000 micropipettes), but there were no differences among any of the other three groups.

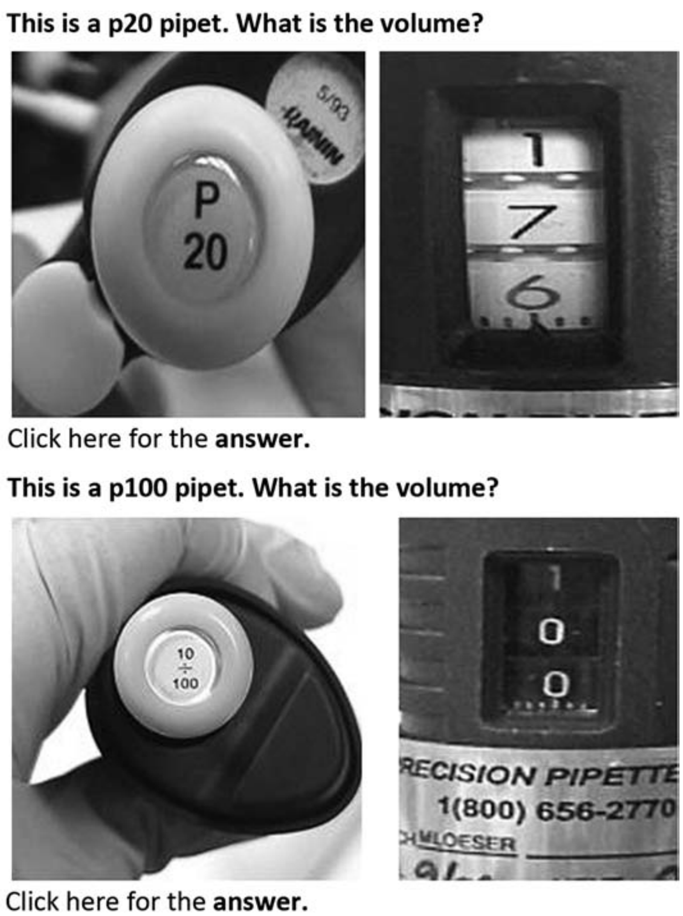

Figure 2. Pictures of micropipettes that were provided to students. A picture of a p2 and a p100 micropipette was taken from the top of the pipette, so students could see what kind of a pipette was being used. A picture was also taken of the settings on the pipette. These pictures were posted on an interactive website. After students determined what the volume was, they could then click on the link for the answer to verify that they had the correct one.

Balancing a Centrifuge Rotor & Reading the Setting on a PCR Machine

The students also needed to learn how to properly balance a centrifuge rotor and how to read the settings on a PCR machine. Digital pictures were taken of these pieces of equipment and were placed in a PowerPoint presentation that I included during class discussions and lectures (Figure 4).

On the subsequent exam, the students were given a picture of a rotor and asked to explain how to balance it; 96.7% of the students were able to correctly answer the question. They were also given a picture of a program set on a PCR machine and asked to state the annealing temperature and time; only 73.2% were able to describe the PCR settings correctly (Figure 5). The data from these two pieces of equipment were statistically different ($P < 0.05$), which suggests that learning how to use one piece of equipment may differ from learning to use another.

Using Pictures from the Lab Manual or Internet to Identify Pictures of Different Equipment

This part of the study used pictures, but they were not digital ones that had been taken in the laboratory. At the beginning of the semester, the students were divided into three groups and given a tour of the lab. Some of the different equipment that was to be used during the course of the class was shown and its use explained. A PowerPoint presentation was made that included pictures from the manufacturer's or other websites (Figure 6A–D).

These pictures showed an ethidium bromide stained gel, a protein tank, a protein gel box, and a white light box used to view protein gels or methylene blue stained DNA gels. On the exam, students were asked to identify these pictures. There was no statistical

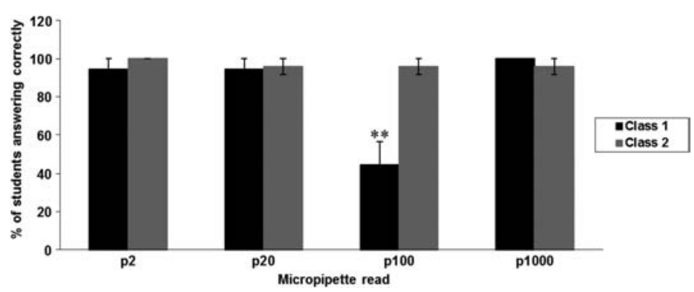

Figure 3. Success rate of students on exam questions that required them to read different micropipettes. During the exam, there was a station where students had to read a volume on a p2, p20, p100, and p1000 micropipette. The success rate of the 18 students on the questions was determined. Bars represent the mean ± SE. Data are from both classes analyzed separately (**$P < 0.001$).

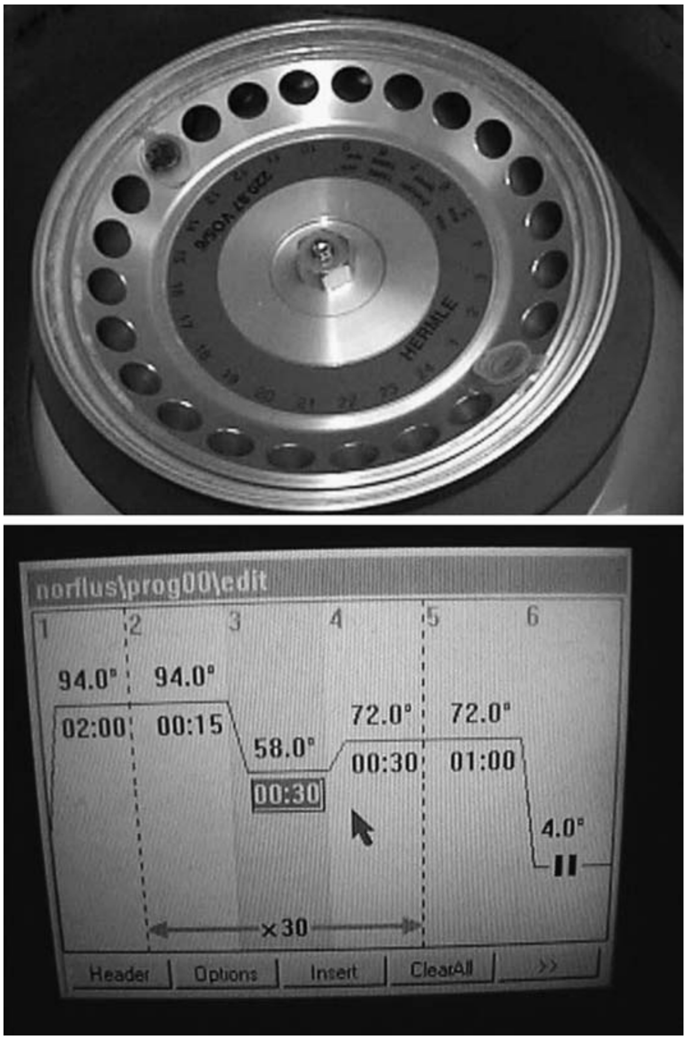

Figure 4. Pictures of a correctly balanced centrifuge rotor (top) and settings on a PCR machine (bottom).

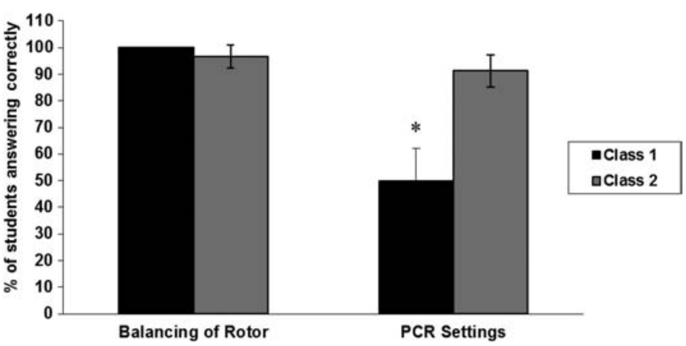

Figure 5. Success rate of students on exam questions that required them to balance a centrifuge rotor and to read the settings on a PCR machine. During the exam, students were asked to look at a picture of a rotor that had two tubes in it and determine where to place the third tube in order to have the rotor balanced. They were also asked to look at the settings from a PCR machine and state the annealing temperature and time required. The success rate of the students on these questions was analyzed. Bars represent the mean ± SE (*P < 0.05). Data are from both classes analyzed separately (*P < 0.05).

difference between any of these groups, but the data show that the students were not 100% proficient in answering the questions. Additionally, class 2 performed significantly better on the ethidium bromide stained gel than class 1 (Figure 6E).

Summary of Success on All the Questions

Overall, 10 digital-photography and 13 non-digital-photography questions were analyzed. The results show that there was no difference between these two groups in the first class. However, the second class showed a significant difference ($P < 0.05$). I hypothesized that these differences may be related to only learning about the different techniques. Therefore, I reanalyzed the data but did not include questions 1–6 or 12–15. These were the questions related to the techniques or equipment. When I performed this analysis, although there was some variability in both groups, with some questions answered correctly and others with a success rate significantly less than 100%, there was no statistical difference between the digital-photography questions (questions 7–10) and non-digital-photography questions where the techniques were excluded (questions 16–24) (Figure 7).

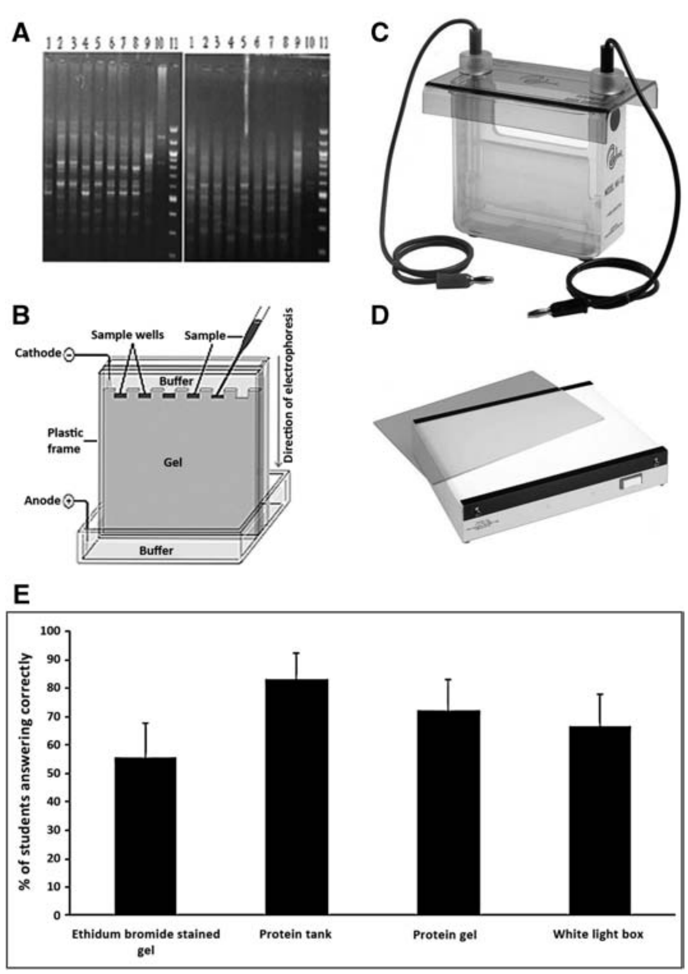

Figure 6. A PowerPoint presentation was made that the instructor went over in class. It contained pictures of (A) an ethidium bromide stained gel, (B) a protein gel box, (C) a protein tank, and (D) a white light box. (E) Success rate of students on exam questions based on these pictures. Bars represent the mean ± SE.

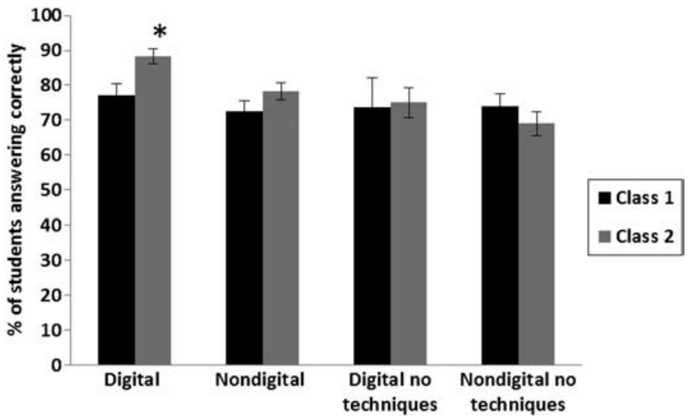

Figure 7. Success rate of students on digital-photography-based and non-digital-photography-based exam questions, and the same categories with the technique questions excluded. On the basis of questions from three examinations, the success rate of the students was analyzed from 11 digital-photography-based questions, 13 non-digital-photography-based questions, 4 digital-photography questions with techniques excluded, and 9 non-digital-photography questions with techniques excluded. Bars represent the mean ± SE (*$P < 0.05$).

○ Discussion

When the technique questions were omitted, there was no statistical difference between the two groups – but this does not indicate that digital photography is not effective. Rather, it shows that a combination of different teaching approaches is required. The use of digital photography was very helpful in enabling the students to learn different techniques, for example to read micropipettes effectively. As noted above, when students need to learn how to use a new piece of equipment, it is very helpful to have pictures for the instructor to demonstrate the technique rather than have an entire class of students surround a piece of equipment.

Although some students entered the class with more experience and abilities than others, I noticed at the beginning of the class that many students did not know how to use the pipettes. Therefore, they were instructed to study the pipette images posted on the interactive website. The performance of the students on the exam showed that their ability to read pipettes had greatly improved. Additionally, although early in the semester the students had difficulties and the volumes they pipetted were inconsistent, they were more proficient in using the pipettes later in the semester. I have since instituted a skills test to ascertain whether the students are able to accurately use the pipettes to measure the appropriate volumes.

The students had some difficulties in identifying pictures from the lab manual or Internet. However, some of the lab-manual pictures displayed equipment that had been shown to the students but had not yet been used in the class. This may have made the questions more difficult for the students. It should be noted that this study did not compare the success before and after using digital photography. It might be interesting in the future to test the students when they first enter the class as well as after they are exposed to the material. Also, different groups of students should be analyzed: some should be shown the pictures, and others receive only a verbal explanation of the concept. This study could also be expanded by analyzing each student's performance individually and determining whether they are more successful on questions based on digital photography or on the other questions.

The methods presented here can benefit other teachers who have even larger classes of students. In addition to keeping up with the ever-changing learning methods of our students, the use of digital photography limits the number of faculty or teaching assistants required for a class.

○ Acknowledgments

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