6-1-2010

The Gel Documentation System: A Cornerstone to the Implementation of the Introduction to Biotechnology and Introduction to Bioinformatics Cross-Disciplinary Course Series

Marcy Kelly
Dyson College of Arts and Sciences, Pace University

Gregory Lampard
Dyson College of Arts and Sciences, Pace University

Constance Knapp
Seidenberg School of CSIS, Pace University

The Provost's Grants for the *Thinkfinity* Initiative for Innovative Teaching, Technology and Research Interim Report

Title of Project: The Gel Documentation System: A Cornerstone to the Implementation of the Introduction to Biotechnology and Introduction to Bioinformatics Cross-Disciplinary Course Series.

Cornernerstone #: 3, Interdisciplinary Informatics

Principal Investigators:

Marcy Kelly, PhD – Dyson College of Arts and Sciences, Department of Biology and Health Sciences
Gregory Lampard, PhD – Dyson College of Arts and Sciences, Department of Biology and Health Sciences
Constance Knapp, PhD – Seidenberg School of Computer Science and Information Systems

Date: June 1, 2010

Goals:

Our goal was to offer Pace undergraduate students an opportunity to be introduced to both Biotechnology and Computer Science as it relates to Bioinformatics. We proposed a two course series, offered to both computer science and biology students that will increase both biological and computer science literacy of our students. The two courses are Introduction to Biotechnology (BIO 372) and Introduction to Bioinformatics. Because technology is a major component of both courses it is imperative that we offer our students the opportunity to utilize technologies that are current with industry standards. To that end we are asked for and received funds to purchase a Digital Imaging System (henceforth referred to as a GelDoc System) that would be utilized in both courses. The system allowed us to implement technology that meets current Research and Industrial standards while also giving us the ability to upgrade the technology in the future.

To assess the impact of the GelDoc system on student learning in the two courses, we proposed the following outcomes and assessment tools:

Table 1.

Outcome	Assessment Tool
Ensure proficiency in the mechanisms and software used by molecular and systems biologists to access, manipulate, and interpret vast amounts of data (including the GelDoc System).	1. Develop pre-test and post-test open ended questions that evaluate the students' knowledge, experience, and confidence with the data analysis software in the course. These questions will be distributed to the students prior to and following usage of the of the data analysis software. The answers to the pre- and post- test questions will be analyzed using statistics. 2. Develop a Student Assessment of Learning Gains (SALG) survey to determine the perceptions the students have about their proficiency with respect to the data analysis software in the course.
Ensure that the students realize that computer generated predictions of biological behaviors must be validated experimentally using tools such as the GelDoc System.	1. Observe and question students while they work with the GelDoc System to ensure that they realize the connections between their computer generated predictions and the biological behaviors they are observing using the GelDoc System.
Enhance the students' ability to conceptualize bioinformatics techniques by providing the students with experimental tools such as the GelDoc System.	1. Develop open ended exam questions that require the students to apply the knowledge that they have gained from the GelDoc System to new bioinformatics scenarios.
Increase cross-disciplinary literacy in bioinformatics to enhance communication and collaboration between biologists and computer scientists.	1. Require that the students perform their experiments and data analysis in groups in the laboratory. Observe the interactions between the students during their group-work. 2. Require that the students present and discuss their findings regularly in lecture and laboratory.

Progress to date:

We offered the Introduction to Biotechnology (BIO 372) course during the Spring 2010 semester on the Pleasantville campus. The course was developed and taught by Dr. Gregory Lampard, one of the PI's for this Thinkfinity grant. Twelve Pleasantville Biology and Health Sciences majors and one New York City Biology and Health Sciences major enrolled in the course.

The laboratory component of the course was designed to walk the students through the production of a transgenic plant following a series of laboratory exercises. In the completing this task, the students first learned how to produce proteins using microbial bioreactors. In order to assess the quality of their protein purification, the students analyzed and documented their results using gel separation technology, which was assessed using the Coomassie Brilliant Blue staining/white light imaging capabilities of the GelDoc system. These exercises were followed up with functional tests of the purified protein which were interpreted by analyzing the end-products of the procedure. This relied on viewing, assessing, and quantifying fluorescently labeled DNA molecules using the DNA intercalating agent/UV light imaging capabilities of the GelDoc System.

The GelDoc System was also utilized by students enrolled in the laboratory component of BIO 372 to assist them in the generation of trangenes. Transgenes are genes that have been transferred from one organism to another. In order to create the specific transgenes, the students spliced two or more pieces of DNA together. While there are multiple techniques that are available to visualize the successful attachment of two pieces of DNA together, each technique is contingent upon being able to visualize DNA, which as previously described requires a GelDoc System.

Finally, the students were required to learn about the processes involved in making transgenic bioreactors in the BIO 372 laboratory. The process of making transgenic bioreactors is relatively inefficient. This is due to many factors, but this fact necessitates the implementation of early diagnostic tests to screen for A) the insertion of foreign DNA into the host organism and B) the subsequent functionality of this newly inserted DNA. The students examined mock expression data that would come from these two classes of tests. The mock expression data analysis required not only the visualization of DNA on gels, but also required quantification of the amount of DNA present in each gel. This could only be conducted using the image analysis software that is associated and supplied with the GelDoc System.

From the above description of the experiments the students performed in the BIO 372 Laboratory, it is clear that the GelDoc System was widely utilized throughout the semester. The central nature of this piece of equipment in the course clearly illustrates why it is necessary that out students develop a practical understanding of this technology.

To assess whether or not the students gained a practical understanding of the GelDoc technology, we designed a pedagogical study involving the outcomes/assessment measures listed in Table 1, above. We applied for and received Pace University IRB approval for this study in January 2010 (IRB approval # 10-03) and initiated the study with the Spring 2010 BIO 372 students. An initial analysis of our data demonstrates that the students did indeed gain a practical understanding of the GelDoc technology. Preliminary details of that analysis are described below.

Impact of the project on students.

To determine the impact of the GelDoc System on student learning, we sought to determine whether the utilization of the GelDoc system enhanced the students' ability to analyze data generated from molecular biology experimentation in BIO 372 and Bioinformatics. To these ends, for each course, we developed the following outcomes/assessment tools based upon the information described (Table 1):

Outcome 1: Be proficient in the mechanisms and software used by molecular biologists to access, manipulate, and interpret vast amounts of biological data (including the GelDoc system).

Assessment 1: Develop a pre-test, mid-semester-test, and post-test with similar open ended questions to evaluate the students' knowledge, experience, and confidence with the data analysis software in the course. The students' answers will be coded based upon complexity and compared to the PI's answers to each question. They will then be analyzed using statistical tests such as paired and unpaired *t*-tests. An example of a test that was used in the BIO 372 course is included in Appendix A of this report.

Assessment 2: Develop a Student Assessment of Learning Gains (SALG) survey to determine the perceptions the subjects have about their proficiency with respect to the data analysis software in the course. The SALG is a Likert-type survey that asks the subjects to rank each question from 1-5 with 1 being the worst response and 5 being the best response. The responses to each question will be used to determine the mean subject response. The SALG does have some summative questions at the end of the survey. These questions will be coded for analysis. The SALG survey that was used in the BIO 372 course is included in Appendix B of this report.

Outcome 2: Realize that computer generated predictions of biological behaviors must be validated experimentally using tools such as the GelDoc system.

Assessment 1: Observe and question subjects while they work with the GelDoc system to ensure that they realize the connections between their computer generated predictions and the biological behaviors they are observing using the GelDoc system. Subject observations and comments will be documented, coded, and analyzed for complexity.

Outcome 3: Conceptualize bioinformatics techniques through the usage of the GelDoc system.

Assessment 1: Develop open ended exam questions that require the subjects to apply the knowledge that they have gained from the GelDoc system to new bioinformatics scenarios. Sample questions from the BIO 372 course are included in Appendix C of this report.

Thus far, we have collected and begun to analyze the data obtained from the Fall 2010 BIO 372 students.

With respect to the pre-, mid semester- and post – tests, 13, 12, and 11 students took the tests, respectively. The questions on the tests were identical and are provided in Appendix A. The pre-test was given to the students on the first day of BIO 372 laboratory. The mid semester test was given to the students in the laboratory one week prior to their laboratory mid-term examination. The post-test was given to the students in the laboratory one week prior to the laboratory final examination.

The first question on the test asked the students if they had ever performed agarose gel electrophoresis. Every student on every test answered, "yes" to that question. For the second question, students were asked in which course they had performed agarose gel electrophoresis. The student answers varied but, the most common courses listed included the laboratory sections of BIO 231 (Genetics), BIO 335

(Cellular and Molecular Biology), and BIO 480 (Research in Biology). Results have been coded from Questions 3-9 (Figure 1).

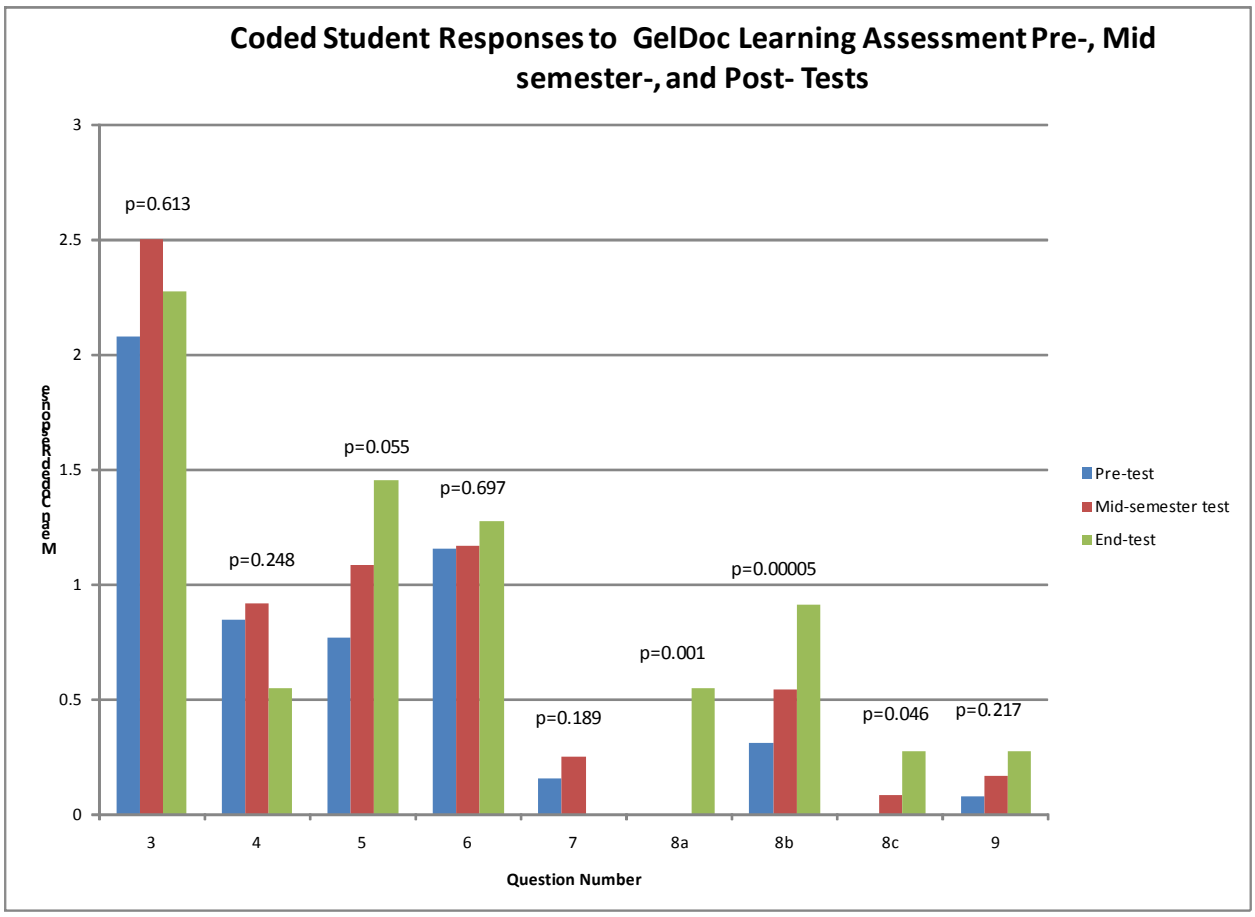


Figure 1: Coded results from Questions 3-9 of the pre-, mid semester- and post-tests.

Overall, as the students learned and utilized the GelDoc System throughout the Spring 2010 semester, they gained a greater understanding of how to access, manipulate, and interpret vast biological data (Figure 1). The differences between pre-test and post-test coded responses were for questions 5, 8a, 8b, and 8c were considered to be statistically significant (Student' unpaired *t*-test, statistical significance was determined as $p \leq 0.05$). Although not considered statistically significant, as students progressed through the semester, they provided more complex answers to questions 6 and 9. A further analysis of the answers to questions 3, 4, and 7 is required to understand why the students' answers decreased in complexity over the course of the semester.

In addition to the pre-, mid semester- and post- test results, a preliminary analysis of the SALG results demonstrated that the students perceived they gained proficiency with respect to molecular data analysis due to utilization of GelDoc System throughout BIO 372. For example, when the students were asked how well they now understood agarose gel electrophoresis as a result of their work with the GelDoc System, 80% of them felt that the system helped them "a lot" or "a great deal". All of the students thought that the GelDoc system helped them understand the importance of staining genetic material for

visualization, the intricacies of the polymerase chain reaction (PCR) technique, and DNA fragment isolation for cloning. Next, 70% of the students agreed that the GelDoc System helped them to understand the importance of quantifying genetic material. Finally, 80% of the students felt that the GelDoc System helped them make gains in understanding the concepts involved in the building of a genetically modified plant and 80% of the students asserted that the GelDoc System helped them feel comfortable with the complex ideas associated with molecular biotechnology.

Several students supplied comments on the SALG with respect to the impact of the GelDoc System on their learning. Sample comments included:

By using the gel documentation system in BIO 372, I definitely gained a lot of knowledge on how it works, what it is used for, how to observe and read the gels, and what the gels show.

The use of the gel documentation system will be beneficial in the continuation of my scientific education.

The gel doc system provided a clear, easy way to visualize the end products of the various steps in the biotechnology lab sessions. It provided a solid point of reference when looking back on the experiments and studying for exams.

In summary, a preliminary analysis of our data has demonstrated that the purchase and untilizaiton of the GelDoc System in the BIO 372 course benefitted the students enrolled in the course as it enabled them to become active participants in their own education; which resulted in enhanced learning. In addition, successful mastery of the complex molecular biological ideas that utilization of the GelDoc System highlighted will enhance the students' attractiveness for graduate or professional school admissions and/or molecular biology laboratory job placement.

Impact of the project on other faculty:

The research faculty in the Department have used the GelDoc System to teach tresearch students enrolled in our two research courses (BIO 292 and BIO 480) about different molecular techniques. It is anticipated that other faculty will incoporate the GelDoc System in their teaching laboratory courses as they are run.

Next Steps:

1. Complete the BIO 372 data analysis and prepare a manuscript for publication in the American Society for Microbiology's *Journal of Microbiology and Biology Education*.
2. Develop the Bioinformatics course for the Spring 2011 semester on the NYC campus. This course will be developed in conjunction with members of the Seidenberg School of Computer Science and Information Systems.
3. Repeat the above pedagogical study with the students enrolled in the Bioinformatics course.
4. Develop a Bioinformatics track or concentration for Biology and Health Sciences and Computer Science majors.

APPENDIX A

BIO 372 Gel Documentation System Pre-Test

Name _____

Date _____

Please answer each question as completely and concisely as possible.

1. Have you ever performed agarose gel electrophoresis (circle the correct answer)?

    a. Yes
    b. No

2. If yes, in when did you perform agarose gel electrophoresis (if you performed agarose gel electrophoresis as part of a laboratory course, please indicate the coure).

    _____
    _____
    _____
    _____
    _____
    _____

3. What is agarose gel electrophoresis?

    _____
    _____
    _____
    _____
    _____
    _____

4. Why would a molecular biologist use agarose gel electrophoresis?

    _____
    _____
    _____
    _____
    _____
    _____

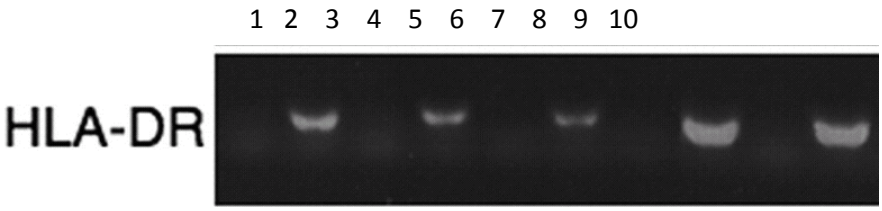
5. How are samples on agarose gels visualized?

    _____
    _____
    _____
    _____
    _____
    _____

6. What kinds of information can a molecular biologist learn from visualizing samples on agarose gels?

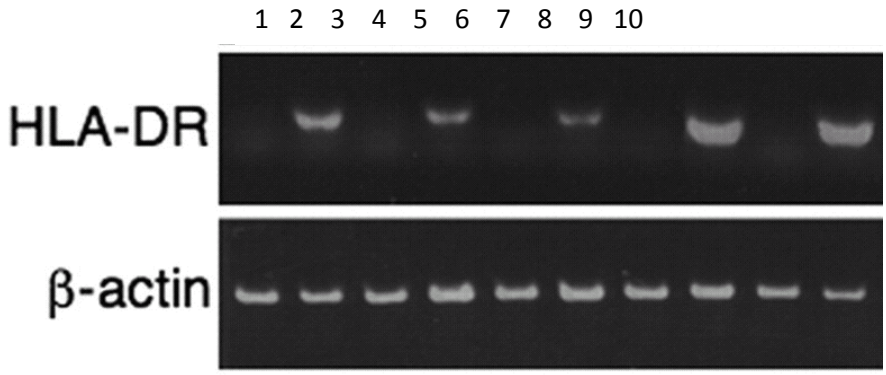
_____
_____
_____
_____
_____
_____

7. Please review the figure below and describe how you would use molecular imaging software to quantify the intensity of each of the spots in lanes 1-10.



_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

8. Refer to the figure below to answer parts a-c.
    a. Describe how you would use molecular imaging software to quantify relative gene expression for each of the HLA-DR samples.
    b. Describe the importance of including the β-actin gene expression data in this process.
    c. What is meant by the term “normalization?”



9. The following data were obtained from the Molecular Analysis software for samples 1-4 above. Using these data calculate the relative expression level of HLA-DR for samples 1-4.

	1	2	3	4
HLA-DR	**0**	**500**	**12**	**210**
B-actin	**500**	**438**	**498**	**622**

Expression Level				

APPENDIX B

Student Assessment of Learning Gains

A survey to assess student perceptions about how the gel documentation system enhanced their abilities to evaluate molecular data.

Pace University - PLV
BIO 372, Spring 2010

Instructions: Check one value for each question on each scale. If the question is not applicable, check 'N/A'.

Q1. How much did each of the following aspects of gel documentation utilization during the course help your learning?

A. The laboratory activities that used the gel documentation system:
   A. N/A
   B. No help
   C. A little help
   D. Moderate help
   E. Much help
   F. Very Much Help

B. Discussion about the gel documentation system in lecture:
   A. N/A
   B. No help
   C. A little help
   D. Moderate help
   E. Much help
   F. Very Much Help

C. Discussion about the gel documentation system in laboratory:
   A. N/A
   B. No help
   C. A little help
   D. Moderate help
   E. Much help
   F. Very Much Help

D. Reading assignments related to gel documentation system utilization:
   A. N/A
   B. No help
   C. A little help
   D. Moderate help
   E. Much help
   F. Very Much Help

E. Interactions with the instructor in the laboratory:
A. N/A
B. No help
C. A little help
D. Moderate help
E. Much help
F. Very Much Help

F. Interactions with peers in the laboratory:
A. N/A
B. No help
C. A little help
D. Moderate help
E. Much help
F. Very Much Help

Q2. As a result of your work with the gel documentation system, how well do you think you now understand each of the following?

Agarose gel electrophoresis:
A. N/A
B. Not at all
C. A little
D. Somewhat
E. A lot
F. A great deal

Staining of genetic material for visualization:
A. N/A
B. Not at all
C. A little
D. Somewhat
E. A lot
F. A great deal

Restriction mapping:
A. N/A
B. Not at all
C. A little
D. Somewhat
E. A lot
F. A great deal

PCR:
A. N/A
B. Not at all
C. A little
D. Somewhat
E. A lot
F. A great deal

-
DNA fragment isolation for cloning:
A. N/A
B. Not at all
C. A little
D. Somewhat
E. A lot
F. A great deal

Quantification of genetic material:
A. N/A
B. Not at all
C. A little
D. Somewhat
E. A lot
F. A great deal

Q4. To what extent did you make gains in any of the following as a result of your work with the gel documentation system?

Understanding the main concepts involved in the building of a genetically modified plant (BIO 372) or validating computer-generated predictions of gene expression data (BIO 399X):
A. N/A
B. Not at all
C. A little
D. Somewhat
E. A lot
F. A great deal

Understanding the relationship between the steps involved in the building a genetically modified plant (BIO 372) or validating computer-generated predictions of gene expression data (BIO 399X):
A. N/A
B. Not at all
C. A little
D. Somewhat
E. A lot
F. A great deal

Feeling comfortable with the complex ideas associated with molecular biotechnology (BIO 372) or bioinformatics (BIO 399X):
A. N/A
B. Not at all
C. A little
D. Somewhat
E. A lot
F. A great deal

Solving molecular biotechnology (BIO 372) or bioinformatics (BIO 399X) problems:
A. N/A
B. Not at all
C. A little
D. Somewhat
E. A lot
F. A great deal

Ability to think through a molecular biology problem or argument:
A. N/A
B. Not at all
C. A little
D. Somewhat
E. A lot
F. A great deal

Ability to communicate complex molecular biology ideas to others:
A. N/A
B. Not at all
C. A little
D. Somewhat
E. A lot
F. A great deal

Confidence in ability to apply molecular biology concepts and ideas:
A. N/A
B. Not at all
C. A little
D. Somewhat
E. A lot
F. A great deal

Enthusiasm for molecular biology:
A. N/A
B. Not at all
C. A little
D. Somewhat
E. A lot
F. A great deal

Additional Questions

Your answers to the following questions will help us evaluate the laboratory and your responses are completely confidential.

1. Was laboratory attendance optional or required by your professor?
    A. Optional
    B. Required

2. How many laboratory sessions did you attend?
    A. None (0)
    B. Not many (1-3)
    C. A few (4-6)
    D. Several (7-9)
    E. Many/All (10 or more)

3. How many times did you use the gel documentation system in the laboratory?
    A. None (0)
    B. Not many (1-3)
    C. A few (4-6)
    D. Several (7-9)
    E. Many/All (10 or more)

4. How much has using the gel documentation system helped you make gains in understanding the main concepts in molecular biology?
    A. A great deal
    B. A fair amount
    C. Some
    D. A little
    E. None

5. How much has using the gel documentation system helped you make gains in understanding the relationship between concepts in this subject.
    A. A great deal
    B. A fair deal
    C. Some
    D. A little
    E. None

6. How much has using the gel documentation system helped you make gains in feeling comfortable with complex ideas.
    A. A great deal
    B. A fair deal
    C. Some
    D. A little
    E. None

7. How much has using the gel documentation system helped you make gains in your ability to solve problems?

A. A great deal
B. A fair deal
C. Some
D. A little
E. None

10. How much has using the gel documentation system helped you make gains in your ability to think through a problem or argument?

A. A great deal
B. A fair deal
C. Some
D. A little
E. None

11. How much has using the gel documentation system helped you make gains in your ability to communicate ideas to others?

A. A great deal
B. A fair deal
C. Some
D. A little
E. None

10. How much has using the gel documentation system helped you make gains in confidence in your ability to do well in this subject?

A. A great deal
B. A fair deal
C. Some
D. A little
E. None

11. How much has using the gel documentation system helped your enthusiasm for this subject?

A. A great deal
B. A fair deal
C. Some
D. A little
E. None

12. What is your class standing? (By credits earned)

A. Freshmen
B. Sophomore
C. Junior
D Senior

13. What is your gender? (Choose "Not specified" if you don't want to answer this question.)

A. Male
B. Female
C. Not specified

14. What race or ethnicity do you most closely identify with? (Choose "None" if you don't want to answer this question.)

A. Black –Non Hispanic
B, American Indian or Native Alaskan
C. Asian or Pacific Islander
D. Hispanic
E. White –Non Hispanic
F. Other
G. None

15. What is your current GPA?

A. 3.5 or higher
B. 3.0 to 3.4
C. 2.5 to 2.9
D. 2.0 to 2.4
E. Below 2.0
F. Don't know

Thank you for answering these questions. Please submit your survey. Remember that your responses are anonymous.

APPENDIX C

1. Describe the steps involved in quantifying spots using the Molecular Imaging software package included with the Gel Logic 212 Pro System used in the lab.
2. When performing semi-quantitative PCR, one must ensure that the PCR reactions are stopped while amplification of both the test- and housekeeping genes are still in logarithmic phase.
    a. What is meant by this statement?
    b. Why is it important to do this?
3. Describe the limitations of the Molecular Imaging software in attempting to determine relative expression levels for minor changes in gene expression.
4. What significant technological development has occurred in the past few years that led to significant improvements and accuracy in PCR-based quantification of gene expression? How does this technology differ from the method of quantification of gene expression you conducted in the lab?
5. Many molecular biological and biochemical techniques rely on Image Collection and Analysis. One of those techniques is Western Blotting that relies on chemilumenescence as an indicator of protein expression. Could we use the Gel Logic Pro 212 to detect signals of this nature? Why or why not?
6. What is the difference between using the Gel Doc System to analyze non-quantifiable data such as the results of restriction digestion versus using it to analyze quantitative data such as relative gene expression patterns?