Madison Area Technical College: Creating a New Learning Environment in the Biotechnology Laboratory Technician Program

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Reader’s Guide

- Note to reader: I want to assure readers that you do not need an in-depth understanding of the protein purification process in order to benefit from this case study. However, to more fully understand the ways in which Jeanette Mowery’s use of learning technology affects student learning, click to the section entitled “What is Protein Purification,” which gives a simple explanation of the process.

- To get an explanation of what Andrew Booth’s Protein Lab does, and how it is used, see the section of this case study entitled “Creating the Learning Environment” and look under the sub header “Protein Purification Simulation Software.”

- The hyperlink Protein Lab takes you to the software’s official web site http://www.booth1.demon.co.uk/archive/ where the software can be downloaded for Macintosh or Windows by clicking on the links with those names. You can also run the program directly on the web by clicking either on the link The Java version (application, awt 1.0), or The Java version (applet, awt 1.1, Swing 1.0.3) depending on what java version you have.

- Special terms appear in the Glossary. The first time one of these terms occurs in a major section, it appears underlined and the definition is available in a mouse-over box. These definitions appear as lettered footnotes.

- All citations to which the case study refers are listed in the References.

- Technical asides are indicated by a numbered footnote marker and available to the reader in a mouse-over box.

- Lengthy quotes from participants that illustrate a point often are available in mouse-over boxes (and also as lettered footnotes), for the benefit of the reader who prefers to read the participants’ own words.

- Various topics introduced in the study are developed at greater length in Discussions (specified by number) to which the reader is referred at relevant points.

- The reader is referred at relevant points to various other Resources (specified by letter). Among these is a short description of the Methods Used to Produce this Case Study (Resource C).

- Of note for users of the web version: Clicking the “previous page” button will take you to the previous linear section of the case study, not necessarily to the page which you last visited. Clicking the “back” button of your web browser will return you to the section last visited.
- We use pseudonyms for the students who appear in the quoted material. To help avoid confusion, the researchers are identified as “interviewer” the first time their voice appears in an interview segment. Lengthier quotes appear in italics.
Summary/Dramatis Personae

Lisa Seidman, Instructor in the MATC Biotechnology Laboratory Technician Program. Lisa discovered and was the first to implement Andrew Booth’s Protein Lab software that is featured in this case study. She received her Ph.D. in 1984 from the University of Wisconsin. In 1987 Lisa and colleagues began a two-year Biotechnology Program to prepare students for entry level positions in emerging biotechnology companies. Since then, she has worked on a variety of courses and projects to help students succeed in biotechnology laboratory careers. She is the author of a textbook “Basic Laboratory Methods for Biotechnology.”

Becky Pearlman, Instructor in the MATC Biotechnology Laboratory Technician Program. Becky is now a lecturer in the Biology Department at Johns Hopkins University in Baltimore, Maryland. While at MATC she taught several courses including Molecular Biology and Protein Purification. Her professional interests include improvement of biology education, along with research in plant genetics and emerging infectious disease.

Jeanette Mowery, MATC Protein Purification Instructor. Jeanette is the featured instructor in this case study. When asked about her experience with the Protein Lab software, she stated,
With the Protein Lab software, my students can separate a protein and have a result, in an hour or less, by clicking. They can do the whole protein purification process. In order to give them that kind of experience in the wet lab, I would have to have a course that lasted forty hours a week, for two years, and I’d still have a hard time doing it. But because you can run a procedure by clicking, it really sends the message home to them of what the protein purification process is actually like.
Introduction
Jeanette Mowery’s “Protein Bioseparations” course: what it is, what happens in class, what changes Jeannette has undertaken and why, and some preliminary results.

The Setting
In this section, we introduce you to Jeanette Mowery and her colleagues and present the information necessary to understand the context within which they strive to achieve their goals for student learning.

Learning Problems and Goals
Here we examine Jeanette’s initial reason for incorporating Andrew Booth’s Protein Lab into her curriculum, the pedagogical problems that it helps solve, and the goals that she and her colleagues have for student-learning.

Creating the Learning Environment
In this section, we look closely at how the MATC faculty created their new learning environments, the tools they use, and the activities they assign.

Implementation
Wondering about the logistics? The MATC faculty share how they did it: from acquiring the necessary resources (money, space, computer-access, etc.), to personal resources such as determination, that allowed them to get over the obstacles that confronted them.

Summing Up
Introduction

What has Jeanette Mowery done in her “Protein Bioseparations Course”? 
Jeanette has integrated simulation software, which was developed at Leeds college, UK by Andrew Booth, called Protein Lab into her “Protein Bioseparations” course, a component of the MATC Biotechnology Laboratory Technician Program. This software provides students a virtual laboratory where they can purify 20 different proteins.¹

Why has she done it?
Although this simulation exercise may seem superfluous in a class like Jeanette’s where, for six hours a week, students engage in real-life protein purification in a wet lab, Jeanette told us that it is, in fact, essential. Because her students’ only real-life experience with protein purification involves a semester long project with one single protein, she says they need something like Protein Lab to show them that the techniques and strategies they are using apply differently to each protein that they may encounter. The Protein Lab software allows them to do this by providing them a virtual laboratory where they can purify many different proteins, and purify each one in an hour or less.

What goes on in Jeanette’s class that doesn’t involve technology?
Jeanette’s students spend one hour a week in lecture, and about six hours a week in a wet lab engaged in a semester long project, the purification of the protein beta-galactosidase. The course is designed to resemble the lab situations her students will face in their future by structuring the lab work as a project, assigning progress reports, and by assessing students’ reliability and interpersonal skills. According to her and her colleagues, this real-life, hands-on work is paramount to assuring students’ future success as lab technicians.

¹ For an in-depth, illustrated presentation of Protein Lab, see the section of this case entitled, “Protein Purification Simulation Software.”
What’s the result of all this education?
Once students in the Biotechnology Laboratory Technician Program have completed the majority of their course work, they are eligible to participate in an internship course that places them in laboratories throughout the Madison area. There they are able to put all of their college work to the test. And they seem to test well! 100% of students who come out of the Program and desire a job in the field receive one.

Jeanette emphasizes that, once the Protein Lab software came along, she no longer had to rely so much on explaining the big picture to her students. Rather, she could put her students in charge of their own learning. From that point on, their understanding of the big picture more closely approximated their conception of the detailed, daily lab procedures they followed. Because of the balance that Protein Lab brought, and continues to bring to her students’ overall experience, Jeanette is confident that those who complete her class will be well-rounded, successful lab technicians.

If you would like to have this kind of confidence in your students, keep reading…

Setting
This case features Jeanette Mowery’s “Protein Bioseparations” course, which is part of Madison Area Technical College (MATC)’s Biotechnology Laboratory Technician Program. It also features Jeanette’s colleagues, their efforts to use instructional technology in their classrooms, their comments on the problems that this technology can solve, their goals for student learning that they wish to achieve by using it, and the implementation issues associated with it.

Learning Problems and Goals
Problems
Jeanette Mowery, instructor of “Protein Bioseparations,” did not start using technology in her classroom for the same reasons that the majority of instructors featured on the Learning Through Technology (LT²) web site did. The majority of professors highlighted in other case studies incorporated computer-enhanced learning activities in order to solve what they saw as a problem with student learning. Jeanette, on the other hand, did not have a particular problem that she was trying to solve when she began using Andrew Booth’s Protein Lab software in her course. Instead, she was introduced to the software by her colleague, Lisa Seidman, instructor in the biotechnology program, who had purchased several different software packages to be used in the Biotechnology Lab Technician Program, and who recognized the potential that Protein Lab had to improve student learning.²

² Marco, interviewer: What problems were you actually trying to solve when you decided to use the Protein Lab?
However, after talking about Protein Lab with Jeanette and her colleague, Becky Pearlman, who also uses the software to teach “Protein Bioseparations,” we found that both of them value the software’s potential to help solve some of the more common problems with student learning that are described throughout the LT² web site.

One of these problems is students’ inability to comprehensively and meaningfully understand a particular concept. This problem applies to Jeanette’s students, who she said would “lose the big picture” without the software because they would spend “so much time doing the actual technique.” In other words, students would learn certain protein separation techniques at certain times, but might not fully grasp the fact that those techniques are a part of a larger, trial and error process. (To understand more about the trial and error process of protein purification, see the section in this case study entitled What is Protein Purification?) One instructor agreed with Jeanette and said that, “when you expose new students to a single process, they tend to think the whole world revolves around those techniques and those issues.” According to him and Jeanette, this limited viewpoint is exactly the wrong one to have if students wish to understand the process of protein purification.

Another opinion that Jeanette and her colleagues share with other instructors featured in the LT² web site is that the lecture approach creates a learning environment that often fails to facilitate meaningful learning. Jeanette told us that if she were only to lecture on protein purification, she would have many students who tried to memorize purification strategies as opposed to seeing it as a process that necessitates trial-and-error.3

**Goals**

The MATC Biotech faculty have several goals that they think will lead to the creation of a learning environment that addresses the problems stated above. The first of these is that they want to convey to students that protein purification is a process that is unique to each protein4 (see, “What is Protein Purification?”). According to Jeanette, students who do not understand this concept will be able to purify beta-galactosidase, the protein on which Jeanette’s students spend a semester, but will not have the experimentation skills that will be necessary in their future positions as lab technicians.

Another faculty goal is to ensure that students do hands-on work, purifying real proteins, in the wet lab both to develop experimentation skills, and self-confidence. A “Protein

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Jeanette: Well, that’s not how it really presented itself to me. I used it because it was here, and it was a teaching tool. And I didn’t really have very high expectations of it because, for one thing, it was pretty old and this was six years ago that I first had it. But when I used it, I was amazed at how well it did the job.

3 Jeanette: Even though I say all through the semester that you can’t memorize a strategy, if they didn’t have something to give them perspective, they would come away from the lesson saying, “Well, when you purify a protein, you do X, Y, and Z.” Lecture material doesn’t get imprinted in the brain quite the same way. It’s just hard for them to think outside the box.

4 Jeanette: Just due to the fact that they do a technique, run a gel and get some data, they start to see how there’s not just one process for purifying any protein. It’s a bunch of different things put together and so much of this comes about through trial and error. I need them to see that all those other techniques are there, and that the lessons they learn are valuable.
Bioseparations” instructor says that, because of the hands-on training they receive, students will have the confidence they need to perform at the same or higher level as any of their future lab colleagues.\(^5\)

Finally, Becky Pearlman, Molecular Biology Instructor, has made it her goal to use technology only inasmuch as it provides an advantage over a textbook. To her, this means something that has an interactive component.\(^6\)

**Creating the Learning Environment**

To achieve their goals for student learning Jeanette and her colleagues have designed their courses as learning environments. In these learning environments, the faculty have incorporated the following types of learning activities:

1. **Computer-dependent activities** that faculty believe simply would not be possible, or at least not feasible, without computers.
2. **Computer-improved activities** that faculty believe work incrementally better with technology but can still be implemented without it.
3. **Computer-independent activities** that can be done without technology.

This section provides explanations and illustrations of those activities. It also presents the views of instructors and students, and how they feel these activities have improved student learning.

**Computer-dependent learning activities**

**Protein Purification Simulation Software.**

Jeanette Mowery uses simulation software called *Protein Lab*\(^7\) in her “Protein Bioseparations” course. The program allows students to simulate the purification of twenty proteins using the same separation techniques that they will use in their future occupations as lab technicians. In this section, we introduce the *Protein Lab* software and give examples of the ways students can learn from it.

*Protein Lab* was created by Andrew Booth in the School of Biochemistry and Molecular Biology at the University of Leeds, England.

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5 *Instructor*: I think the one-on-one, face-to-face personal contact work is important as well as just the absolute fundamental hands-on, do it with your own hands, see it and learn it with your own eyes, ears and hands. When you bring students into the lab, I feel that the personal one-on-one attention you give them is really critical in developing their self-confidence. Because even though our students are often times more skilled in the lab, they still get paid the same amount as students with bachelor’s degrees who may not even have any lab experience at all. There’s a prejudice against tech school graduates. So they must leave our program with a good sense of accomplishment and just feeling good about themselves.

6 *Becky*: If the technology you are using looks just like the textbook, then I don’t think it’s that useful. I think it has to have something above and beyond what the textbook could offer you. To me, anything that has some kind of interactive component is better for the students. I’m not crazy about just question and answer, but it’s better than just having to read something online. And I know people say, “Oh, but it has hyper links.” I’ll say, “Yeah, a textbook has an index too.”

7 Booth, A. G.,
The program can be run and the software downloaded (For Macintosh or Windows) from the Web site http://www.booth1.demon.co.uk/archive.

In her computer lab, Jeanette’s students choose a protein (1-20) to purify. Although the proteins are not named, they are patterned on actual proteins. Based on their choice of 1-20,

Diagram 3.1—Students choose protein number.

the student receives basic information about that protein (in this example, number 8) including pH and temperature stability range.

Diagram 3.2—Information about pH and temperature of protein.

According to Jeanette, the actual names of specific proteins do not need to be included in the simulation. She said that because there exist hundreds of thousands of proteins, because the process for purifying each of these proteins is unique, and because students might encounter any one of these proteins in their future jobs, including the names of the one through twenty that students see in the simulation would be superfluous. Names would not help them conceptualize the trial and error process that is needed to purify any protein.

All diagrams of Protein Lab were taken as screen shots from http://www.booth1.demon.co.uk/archive.
The student then chooses from several pull-down menus: Separation, Electrophoresis, Help. From the Separation menu, techniques such as ammonium sulfate precipitation, heat denaturation, gel filtration, ion exchange chromatography, hydrophobic interaction chromatography, preparative isoelectric focusing, and affinity chromatography can be chosen.

If, for example, a chromatography technique is chosen for separation, the computer generates a chromatogram of $A_{280}$ vs. fraction number.
From a pull-down menu titled Fractions, the fractions can then be assayed for enzyme activity and selected fractions pooled.
Students can then run one-dimensional and two-dimensional Page gels and immunoblots to assess purity. They do this by selecting from the pull-down menu entitled Electrophoresis.
These are the results of an SDS Page gel.
After gel results, the next separation technique can be chosen. Progress reports are given on yield, enrichment and efficiency (expressed in person hours).

**Why does Jeanette use this software?**

**Jeanette:** *Some students could understand the concepts of this class without the computer. But my sense of it is that the simulation is very very helpful, both to emphasize the concept that the purification is a trial and error process that is unique to each protein and to give them an understanding of what the project is before they start the class.*

As we can see from her statement above, Jeanette uses the Protein lab for two main reasons:

1. **To emphasize to her students that the optimal strategy for purifying any protein is unique, and will be optimized through their own trial and error.**

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10 **Jeanette:** The process you use to purify any single protein is not something you can apply to every protein on the planet. You can’t just use one method. You have to use a series of methods in order to get your protein. And the way you discover what series is best is by trial and error. For example, it might be better to do gel filtration before you do ion exchange. It might be better to do ion exchange before you do gel filtration. And you won’t know that unless you try. The most important thing for students to know is
2. To give her students experience with protein purification before they know anything about the process. (Curt Hieggelke, a physics instructor featured on this site, referred to this early familiarization by immersion process as, “filling the blank screen” http://www.wcer.wisc.edu/nise/ilt/case/joliet/joliet.htm.)

In regards to her first reason, Jeanette told us that there is no uniform way to purify any single protein. According to her, if you try to use the same purification process for every protein, “you’ll purify the protein that you purified last time, but you won’t get the one you want.” The computer simulation facilitates her students’ understanding of this process by offering a variety of different proteins for them to purify, and allowing them to perform the entire protein purification process in less than an hour. During the simulation, students are able to experiment, on their own, with various separation techniques and strategies. Jeanette gives an example of how this experimentation works:

Jeanette: If you pick ammonium sulfate as your separation technique and type in 35%, it will run the technique, come back and say, for example, that you have just precipitated 95% of the target protein and 60% of all other proteins. Without taking the time to do the actual procedure, you’ve precipitated 95% of the protein. I tell students that in real life we would accept that percentage because we lose a little bit from all the manipulation. But, what’s nice about the simulation is that at that point you can go back and say, “I really want to use 50% ammonium sulfate.” By changing the level of your ammonium sulfate precipitation, you can experiment to get 100% of your protein. So, in three clicks of a mouse they have a result.

Jeanette told us that if students were to experiment the same way in the wet lab, she “would have to have a course that lasted forty hours a week, for two years, and would still have a hard time doing it.” She told us that, although computer simulations can never replace the invaluable hands-on experience that students gain in the wet lab, Andrew Booth’s Protein Lab is very useful in its ability to help students meaningfully understand that the purification process is unique to each protein.

As stated above, Jeanette also uses Protein Lab in an effort give her students a feel for what the protein purification process is like before they actually start doing it. According to her, “There’s no way you can give them a lecture on the whole course and then have them do it. Doing simulations that resemble what they will be doing in the lab reinforces what they’re about to do.” Her colleague, who has also taught “protein bioseparations,” agrees with Jeanette’s ideas. He told us that it is impossible to give students a conceptual

that there isn’t just one way to do it. And the only way for them to discover the optimum way of doing it is by trial and error. That’s the point I’m trying to drive home to the students. And this is how real life works.  

Jeanette: The fact that you can just generate a chromatogram without having to run a column and pick the fractions gives them familiarity with what they get to in the wet lab.
picture of the techniques involved with protein purification unless they actually work with those techniques.12

Jeanette’s students appreciate the software for the same reasons. When asked why they think Jeanette uses the simulation, one student replied.

Laurel, student: It was a way of visualizing what we were going to do. It was like a learning tool to make us start thinking. I just kept doing different things at random, and eventually I started to figure things out.

To read a more in-depth faculty and student discussion about the ways Protein Lab and other computer-dependent learning activities affect student learning, see Discussion 2.

Computer-independent learning activities
To achieve her goals for student learning, Jeanette and her colleagues use the following computer-independent learning activities.

- Semester long project: the purification of beta-galactosidase.
  - Progress reports that resemble those they would see on the job in a biotech company.
  - Lab notebooks in which students log their daily progress.
- Quizzes, tests, homework.

These activities give students the preparation they will need in their future jobs as lab technicians.13 For example, Jeanette’s students spend the majority of their time throughout the semester in the wet lab where they purify beta-galactosidase. According to Jeanette, the fact that the students work on a project as opposed to a series of individual experiments is itself an imitation of real life experience.14 During this project students experiment with protein separation techniques,15 use trial and error to find the best combination of these techniques, and run assays and immunoblots16 to monitor their progress. While they are working on the project, Jeanette has her students write progress reports,17 much like they would have to do in their future jobs.18 Jeanette assigns these

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12 Instructor: Without a picture in their own mind of the equipment and how to manipulate it before they get started, it’s just words. I can show all the stuff on the board and it doesn’t make any sense to them. After they’ve done it with their hands, it comes so much faster than when I talk about it. It’s a foreign language to talk about something like column chromatography before they’ve actually done it.
13 To see the actual activities: including progress reports, exams, and quizzes that Jeanette assigns in her class, see Resource B.
14 Jeanette: This is a real-world class because, like lab technicians, they do a project that lasts the whole semester as opposed to something that you can conclude in three hours.
15 The techniques include the same ones students see during their work with the Protein Lab: ammonium sulfate precipitation, heat denaturation, gel filtration, ion exchange chromatography, hydrophobic interaction chromatography, preparative isoelectric focusing, and affinity chromatography.
16 See Glossary for definitions of these terms.
17 To see an actual progress report that Jeanette uses, see Resource B.
18 Jeanette: We try to do real world type assignments. Some technicians would be doing very routine tasks and would not have to do that, but we don’t teach to that level. We teach to a best practice level and the best practice would be reporting to a supervisor on what they’ve done on paper and in person. And we make them present that early in the semester. For example, at a company they would probably have to write
progress reports twice a semester but also has her students keep lab notebooks where they report their daily progress. The notebooks are common to most courses in which lab work is done, whereas the progress reports are a more formal, real-world summary of their work.

Jeanette also assigns homework that requires students to read about procedures before they come to class, and make flow charts, which are outlines of what they’re going to do that day in the lab. These assignments are preparatory and ungraded. Jeanette’s quizzes, according to her, “aren’t real in-depth” and cover topics such as how certain separation techniques, like ion exchange, work. On her exams she asks technical questions about processes and procedures while also giving students hypothetical lab situations that they must work through. To see the actual quizzes and tests that Jeanette gives, see Resource A.

This real-world training that students receive in both Protein Bioseparations and other courses in the Biotechnology Laboratory Technician Program leads students to the final stage of the Biotech Program; the internship course. As part of this course, students who have demonstrated that they are capable of performing in actual lab settings\(^\text{19}\) start working in Madison area biotech laboratories. The students work as both employees and students, spending 20 hours a week on the job and one hour a week in class discussing what they have been doing at work. Because of the training students receive in this course, Becky Pearlman, who teaches Molecular Biology and other courses in the Biotech program, calls the internship class “one of the big strengths of the Bio-tech program.”

To read a more in-depth faculty and student discussion of how Jeanette’s computer-independent learning activities prepare students for real-world lab work, see Discussion 2.

**Computer Improved Activities**

To teach her students DNA fingerprinting, Becky Pearlman, molecular biology instructor, uses an online tool called [Trackstar](#) which annotates and organizes web sites around a coherent theme. This organized compilation is called a [track](#), and any instructor can build one by assembling web sites in a way that they feel will be most useful to their students.  

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19 Jeanette: If they can pass this class then they’re probably ready to do the internship.
20 DNA Fingerprinting is the name of Becky’s track
students. Becky’s track on DNA Fingerprinting and Bioinformatics offers her students general information, like the following page entitled “DNA from the beginning.”

It also offers interactive learning tools. From the following menu, students can select topics that allow them to, among other things, test their skills at determining who is guilty in a murder case, or determining who the parents are in a horse breeding scenario.

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21 Becky also has other tracks featured on the site which include: Animations of Enzyme Function; Identification of Bacteria Using Ribosomal DNA Analysis (winner of “Top Track Award” by managers of the site); Using Excel to Graph Assay Data; and Using PowerPoint to Make Presentations. All of the tracks can be found at trackstar.hprtec.org.
Becky’s track also allows students to take online quizzes on topics such as paternity testing. The following screen is an illustration of one of these quizzes that allows students to get explanations about why their answer is correct or incorrect.
When integrated together, the web pages that make up this lesson help students get what Becky calls “the big picture of what you’re teaching and learn a little bit about how to apply it.” Although she wouldn’t need technology to teach the same topics, and indeed she continues to also use more traditional teaching approaches like lecture and group presentations, she claims that organizing lessons in Trackstar is superior to lecture because it allows students to take an active part in their own learning.22 In fact, more than anything, Becky emphasized the interactive aspect of her track, saying that it would be a waste of time for students to even use the technology if not for this component.23

Becky uses TrackStar about twice a semester in Molecular Biology courses24 to give her student supplementary information about and hands-on experience with the topics she was covering in her class. She says that in some ways TrackStar can replace a lecture. She views it as “an alternative way to transmit information to the students, or better yet, to have them discover it themselves.”

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22 Becky: I really hate having to stand up and lecture them. Some of them get upset because that’s how they’ve always been taught, and they feel we should change it. I feel like the more things I can do where they’re actually doing something, the better.

23 Becky: If I’m going take the time to take them up to the lab, check out the classroom, get them all up there, get them to sit down and do something, then I think they should do something interactive, something different from what they usually do.

24 Since we began writing this case study, Becky has accepted a teaching position a Johns Hopkins University where she continues to use TrackStar in many of the same ways she did at MATC.
Implementation

Throughout the process of creating a technology-enhanced learning environment, Jeanette and her colleagues faced many daunting obstacles such as: difficulty securing funding, getting software and computers to work right, and finding space and extra time to reform their teaching practices. In this section, we examine the intricacies of these problems and talk about ways that Jeanette and her colleagues contended with them. In particular, we consider the personal characteristics and networking that can aid the implementation process.

Funding

The Biotechnology program receives the majority of its funding from state-funded MATC. Despite the generally adequate financial support that Jeanette and her colleagues receive from the administration, they are sometimes forced to make do with limited resources. When Jeanette first started using Protein Lab in her “Protein Bioseparations” course in 1994, the program ran only on Microsoft Windows 3.1, which the college no longer had financial resources to support. Now that she has used Andrew Booth’s (the man who developed Protein Lab) web site to upgrade the software to run on Windows 95 and 98, it is much easier for her to get the support she needs. Moreover, now that Jeanette has incorporated Protein Lab into her regular instruction, it is easier for her to present a clear plan for the funding she needs, something that one MATC central administrator says is essential. If funding for the Biotech program continues along the same path, the future looks bright.

Intellectual Property

One instructor in the Biotech Program, however warns that funding is not all that this or any innovative program needs to continue to flourish. According to him, what is more important is that the people who develop bold new pedagogical innovations retain their ownership of them as opposed to transferring ownership completely over to the institution.

25 Central Administrator: I believe that if you’re going to make this happen you have to give people the tools and funding to make it happen. You just don’t say, “Do it,” and pretend it’s going to happen.
26 Marco, Interviewer: Do you feel that Jeanette is supported in her attempt at using technology?
Lisa Seidman, Biotechnology Program Instructor: No, she’s had a lot of trouble. But, again, I don’t think that’s because somebody’s being malicious. I think it’s because people are struggling right now. The institution has tried to put some money into it, but they do not have enough money for software support.
27 Central Administrator: We want to know in September that we need to set aside the right amount of funding, and not wait until the second semester to see if there’s any of this money available. To do that we need to answer the questions, “What are we trying to do here? What are we trying to achieve?” We need these answers not to be controlling but to be more responsive and supportive.
28 Instructor: What a lot of the faculty don’t understand is that there’s a cost to developing instructional tools, and that is that the institution will claim the ownership over it. When it comes to developing new computer-enhanced activities, the question is “Who owns the product?” The institution would like to believe that they own everything that goes on between your two ears, but that’s not been proven one way or the other in the courts. There are people in the institution who are writing CD-ROMs and, essentially,
Access to Computers

Generally, there is no shortage of computer access at the MATC campus. There are labs\textsuperscript{29} and even computers in the hallways with many of the applications that students need in order to do their work. Indeed, many of the students we talked with said that they do the majority of their computerized class assignments on campus.\textsuperscript{30} This is not to say, however, that MATC faculty are completely immune to the bureaucratic headaches that accompany finding space for computer-dependent learning activities. Some of the instructors we talked with spoke of very common problems, like scheduling issues and limitations to their use of computer labs.\textsuperscript{31}

Hardware and Software Issues

Like space issues, hardware and software problems can inhibit efforts to improve student learning, according to Jeanette. Despite the pedagogical advantages of the \textit{Protein Lab} software that she uses, Jeanette told us that in the early phases of implementing it, students were kept from having what she calls “ah ha” moments because of distracting glitches.\textsuperscript{32} Further hampering her instructional effort in the beginning was the program’s signing over ownership because they don’t know any better. Or, they feel their job will be at stake if they don’t do that, and they might not keep their job if they don’t do this activity. And that’s a problem.

If you want somebody to be creative, you’d better let them have ownership of whatever it is they’re creating. They say they’ll pay for it, but that’s not all that’s involved. If your name goes on it, there’s a certain amount of pride associated with it. There’s not going to be a lot of money in anything you do, but there are derivative rights. If they own it, they can take your name off it and change whatever they want. What might be worse is if they keep your name on it and change it whichever way they want. Your name could be associated with something that’s pure trash. I just read a University of Illinois piece on distance education that said one of the most important things was ownership of the materials created. And the institutions, in general, across the country don’t understand that. That’s another reason why I haven’t jumped at opportunities to develop things. I’ve got enough things to do, and that just looks to me like another headache.

\textsuperscript{29} Jeanette: Now we have computer labs that are up and running with the latest basic, fundamental software like Excel and Windows. But before I upgraded the \textit{Protein Lab} software, I only had three computers for an entire class. I couldn’t take enough class time to have them work through it with three computers. But now all I have to do is call the scheduling computer office and say I need a computer lab. So any time I want I can do a computer lab, and use all twenty computers in the lab.

\textsuperscript{30} Marco, Interviewer: Is your main access to computers here at the college? Matt, student: Absolutely.

Marco, Interviewer: Would you go out in the halls, pop in the protein program and start going away?

Laurel, student: Yeah.

\textsuperscript{31} Lisa: You still have to check out a classroom, you have to have one available to you. You have to go up there, it has to be open, and it may or may not be.

Becky: When it gets to be the end of the semester, there are long waits for students to get onto computers. Believe it or not, if I want to use this computer classroom, I have to call the Culinary Arts Department. Don’t ask me why, but for some reason they’re in charge of the computer classroom that I use. The nice thing is that students are welcome to use any computer classroom that’s not being used by a class, and that’s been a positive thing. But, I wish that we had more computer classrooms.

\textsuperscript{32} Jeanette: The original computers had really a lot of glitches that they experienced with the actual software.

Matt, student: It’s kind of hard because everyone’s at a different skill level on the computers. And you kind of get frustrated when the computer freezes and you have no idea what to do. Everyone’s somewhere else, and it’s hard to keep up.
inability to run on computer platforms other than Windows 3.1. Because Windows 3.1 was available on only a handful of computers, several students were forced to huddle around one computer. Moreover, because the 3.1 machines were so outdated, the college’s tech support staff was no longer able to support them. Together, these distracting problems chipped away at *Protein Lab*’s effectiveness and, according to Jeanette, forced them to use the program to function more for demonstration than for hands-on simulation.³³ Now, however, thanks to Andrew Booth, creator of *Protein Lab*, the software is now both easier to use,³⁴ and can be upgraded, for free, to run on Windows 95 and 98.³⁵ As a result, Jeanette can assign her students to use the software at will.³⁶ Although the software does still have its limitations—it can be difficult for those who are just beginning to use it, and it lacks flashy graphics³⁷—the upgraded version of the software allows students to fully maximize the program’s simulation capabilities.

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³³ **Jeanette**: Before I upgraded the software to run on Windows 95 and 98, I had them all hover around the Windows 3.1 machines. There four people to a computer, and the [MATC tech support staff] didn’t even support those computers. I was just happy to get them up and running. So that wasn’t ideal at all. It was sort of like a demonstration, but they got something.

³⁴ **Jeanette**: It’s absolutely no issue at all to run the protein software. You pull down a menu, pick a technique, put in a number and it gives you back data. If you understand what it’s trying to do, it’s extremely easy.

³⁵ To download the software, go to http://www.booth1.demon.co.uk/archive.

³⁶ **Jeanette**: Now I can rely on one of the school’s computer labs, where they have 20 computers in a room. They just run the program from a disk. That makes it a lot easier to demo some things for them. I can go to one of those rooms where they have an overhead and they can follow along with the demonstration. When I click, they can click. So we can do it as a group.

And I think it will be way more valuable now that they can come back to it at will. If they have a disk in their hand at any time, I can make assignments. I can say, “your assignment today is to go purify number four.” I can do all kinds of things that weren’t possible for me to do before because of limited technology.

³⁷ **Jeanette**: I had some initial problems when I was getting it on the web and I thought it was me, but I think it’s really the way he’s got it running on the web. There’s a lot of places in the software where a beginner can get stuck.

Jeanette’s students concur.

**Luke, student**: Each group was over there for about ten or fifteen minutes.

**Matt, student**: I wasn’t satisfied with the amount of time I was allowed to doodle with it. So I sat down and started trying to find different techniques at random, even though I didn’t know what they meant.

**Sarah, student**: I would have liked to have some more graphics in the program too.

**Matt, student**: Well, it’s not that these were great computers.

**Laurel, student**: It might have been the fault of the computer, but it reminded me of old computers where you type some letters in and then letters come out at the end. That’s nice but it’s very uninteresting.
Personal resources

“It’s not the machines, it’s the people.”

Despite the various obstacles that Jeanette and her colleagues have encountered, they have still managed to employ new teaching innovations. This is due mainly to the personal characteristics that the faculty themselves possess, including their determination to succeed despite a lack of software and hardware with which to start off, little financial incentive, and a willingness to place student learning first, independent of financial rewards.

To read a faculty discussion about the importance of determination and motivation when implementing educational reform, see Discussion 4.

Getting Going

The initial stages of implementing technology in the classroom can often be the most taxing. One might know that they want to do it, but feel overwhelmed about how to commence and steer the process. When first starting out on their construction of a technology-enhanced learning environment, the MATC faculty were aided by:

- Their ability to work well together.38
- Speaking directly to the maker of the software they were using.39
- Attending workshops.

They said that by interacting with people who were already involved with the process in some manner, they were comfortable and confident that they too could move down the same path.40 To read a faculty discussion about the importance of networking with colleagues, see Discussion 5.

Summing Up

Perhaps the strongest message that we left MATC with was that there needs to be a balance between giving students hands-on, real life training with the tools, techniques and strategies for protein purification, and giving them a broader, big picture view of protein purification as it exists outside of their college wet lab. The former has no substitute;

38 *Marco, interviewer:* Do the four of you get together and discuss things about technology? Do you have a regular meeting?

*Lisa:* Yeah, we meet Tuesday and Wednesday.

*Flora, interviewer:* Would you say [bringing technology into your classroom] is pretty collaborative?

*Lisa:* It’s pretty collaborative.

*Becky:* I think it’s easier if you’re doing it together with someone. Jeanette and I always complain to each other about something not working.

39 *Jeanette:* Andrew Booth and I have e-mailed each other. So it has given me a new colleague.

40 DuFour and Eaker (1998) refer to this environment of mutual cooperation as a “Professional Learning Community.”
students must be in a lab, using the same instruments and procedures as any lab technician would use. The latter can be taught by using software to simulate a wet lab in which students can experiment, in much less time, with several different proteins.

Concentrating on the real-life purification of one protein to the exclusion of the big picture (i.e. that protein purification is a trial-and-error process unique to each protein) or vice versa can lead either to a lab technician who is not prepared to cope with the uncertainties found every day in lab situations, or to one who knows only how to purify the protein s/he purified in college. Before being introduced to Protein Lab, this is essentially what Jeanette was forced to do. According to her, because the most she could do was explain the big picture, her students received a less than adequate understanding of it.

Once the Protein Lab software came along, she no longer had to rely on explaining the big picture, but could put her students in charge of their own learning. From that point on, her students’ understanding of the big picture more closely approximated their conception of the detailed, daily lab procedures they followed. Because of the balance that Protein Lab brought, and continues to bring to her students’ overall experience, Jeanette is confident that those who complete hers and other classes in the program will be well-rounded, successful lab technicians.

**Discussion 1. What is Protein Purification?**

According to Jeanette Mowery, protein purification is “separating out things you don’t want from things you do want.” Students in Jeanette’s class separate the protein beta-galactosidase from bacteria that hold thousands of different proteins. To do this they use techniques that separate specific proteins from all the others present based on their shapes, sizes, charges, hydrophobicities, solubilities, and functions.

When, for example, a lab technician encounters a new protein, they may receive guidance in purifying that protein from their supervisor. However, students will often know very little about any given protein they encounter, and will therefore be forced to use a trial and error method to purify the protein. To successfully separate it, they must experiment with various techniques, none of which is applied uniformly to each protein. We can start by using the “ammonium sulfate precipitation” technique. Let’s assume that we are trying to purify protein X from a given unit of bacteria. If the salt content of our ammonium sulfate solution is, say, 50% we separate 75% of protein X from our bacteria. (We find out that we have 75% by running tests called assays and immunoblots.) If our boss tells us that 75% isn’t good enough, perhaps we can increase our salt content to 65% and end up precipitating 95% of protein X from the bacteria. However, even though we now have almost all of protein X, our precipitate also includes a lot of other proteins. To separate our protein from all other ones, we choose a new technique. By the time we have successfully separated protein X we will have engaged in an extensive trial and error process on which the successful purification of any protein depends.
Discussion 2: Faculty Discuss Computer-Dependent Learning Activities

As mentioned elsewhere, Jeanette considers the main strength of Andrew Booth’s Protein Lab software to be its ability to allow students to engage in their own trial and error experimentation with a variety of proteins. According to her, students will not meaningfully understand this trial and error process from lecture alone, but rather must be directly engaged in it. In her mind, lecture does not facilitate this understanding in the same way that hands-on work with protein purification can. While students do get this hands-on experience in the wet lab, they can only do so with one protein. The Protein Lab software allows them to test their knowledge in multiple, unique situations. In this section, faculty discuss these issues in depth.

The discussion begins with Jeanette contrasting the DNA purification strategy with protein purification, the former being much more predictable than the latter.

Jeanette: There are only a few ways to separate and purify something like DNA, but proteins are all unique. They all have a unique structure, function, and charge, so there isn’t one way to purify a protein. When you encounter a new protein at a biotechnology company, for instance, and they have you purify a protein that’s never been purified before, you don’t have a prescribed strategy. And that is exactly what the software does. So, it gives them perspective.

An instructor, who also teaches “Protein Bioseparations,” called this perspective a “broadening of horizons.” As he stated (see Problems and Goals section of this case), “When you expose new students to a single process, they tend to think the whole world revolves around those techniques and those issues.” He said that, while purifying beta-galactosidase throughout the course of the semester gives students in depth experience with the process, the simulation teaches them to see the world outside of their classroom.

Instructor: You need to let them know that there’s a lot going on. It’s a real broad-based world, and their learning will not stop here. Using Protein Lab is a way of broadening their horizons and teaching them how to learn. We give them experience in the wet lab of purifying beta-galactosidase, but that’s only one protein out of thousands and we take a semester to do it. The processes used to purify it are not the same as the processes needed to purify other proteins. With the protein software, they can try things, go through all the possibilities and see what the consequences are. There is a chance for a student to make some guesses and do some tests to find out if what they’re thinking is right. They can go through the process and see what would happen.

If you use lecture to do this same thing, you’re going to run into problems because students don’t like to sit and listen for very long. However, if you use lecture to give them just enough to get an idea of what’s going on and then have them do it, you can talk to them because they have a context to put all this information in. So the combination of using new technologies can be quite useful because they work it into a larger context.
Jeanette explained that even she had trouble understanding that protein purification was a process when she first started doing it in college. Although she was immersed in the actual process of it at the time, she did not have the conceptual aid of being able to simulate the purification of many different proteins in a short amount of time. This virtual aid that her students now have; it is one that complements their real-life purification of one protein by giving them ideas about how to go about purifying any protein.

Jeanette: I remember back when I learned how to do these things, and how it took so long to actually see how different techniques fit together, and that what I was doing was a process. The proteins on the simulation are numbered one through twenty, and they’re all different. It sends the very strong message that there are different strategies for proteins and that what works on one doesn’t work on them all. It really helps the students get a sense of the fact that it’s a process. Because in an hour or less they can do the whole process, separate a protein and have a result by clicking.

As we mentioned before, Jeanette also uses the simulation software to familiarize her students with the protein purification process at a very early stage in the semester. In these early stages, the students have little or no knowledge of the protein purification process.

Jeanette: When I first have them do this at the beginning of the semester, I have done an introductory lecture so that they know a little bit about what they’re going to see. I purposely have them do the simulation before they really understand it because even though they don’t understand all the details, they get that it’s a process, and that there’s more than one step. They also get that the goal is to hold on to the enzyme, and lose the rest of the protein. That’s hard to communicate to them if you just do one procedure in the lab.

Her reason for exposing students to such complexity early on is not to make them understand absolutely everything they will need to know, but rather to introduce the topic of protein purification by having them actively participate in it. She says that for this to work, the instructor needs to make it clear to the students that they are not being tested on their abilities and that they are free to make mistakes.

Jeanette: They make a lot of mistakes because they don’t understand how protein purification works. But that’s fine, I don’t expect it to be a perfect situation. I expect them to try something and not have it work at all. Sometimes they try to do an enzyme assay and their protein isn’t there. Well, where is it? It either didn’t stick at all or it’s still stuck, and so there’s things like that that can happen. I keep telling them that I don’t expect anything out of this and that I just want them to get their hands “computer wet.”

Jeanette also said that early introduction to the software helps cut down on the intimidation students sometimes feel when starting off in her class.
Jeanette: Some students come in here intimidated because there’s some lore that it’s a very hard class. And if they didn’t have the computer, they would be intimidated because they would be seeing protein purification in a very linear fashion as it hit them, “Today, class, we are going to assay for beta-galactosidase.” Graduate students even have a hard time with this. So to try to convey a sense of this to two-year associate degree students is a challenge.

Discussion 3: Faculty and Students Discuss Computer-Independent Learning Activities

More than anything, the activities in Jeanette’s class effect student learning by giving them real life experiences. In this section, faculty and students discuss the ways in which they do so.

This discussion begins with Jeanette emphasizing that the students’ lab work not only helps them develop skill in the protein purification process, but also teaches them general work skills.

Jeanette: Their work in lab is a good opportunity to see what their work habits are like: Do they write everything down in their lab notebook? Can they find their stuff? It also gives me a real good opportunity to evaluate attendance, work ethic, preparedness, people skills, how they get along with a lab partner.

Her colleague agrees that these and other real life skills are necessary. He also feels that that is one of the big advantages technical colleges have over universities; they teach the practical skills.

Instructor: The student that comes out of the university without working in a laboratory is at a deficit. You need the same amount of skill to match your understanding of the material. And in fact, if you want to go on to graduate school, you’re going to get the technical experience someway or somehow. If you go to a company, you probably won’t be hired until you get it. They could probably learn the theory in the classroom at a university, but they will not learn how to do it effectively in a real life situation.

Jeanette’s students feel that her class has provided them with exactly that, a real life situation that greatly benefits them in their search for and performance at work.

Luke, student: People in the workforce are really impressed by students from this program.

Sarah, student: I think the hands-on skills, knowledge, and experience we gain here is better than we could get anywhere else.

Marco, interviewer: Does it feel like it’s quite straightforward to get a job after being here?
Luke: Definitely. We’re picking up this hands-on experience of actually carrying out these labs and feeling and learning how everything works. Like reading a PCR (Jeanette, what is this?) – you don’t understand it until you actually do it. That’s why we’re hired, because we have hands-on experience.

Discussion 4: Faculty discuss importance of determination and motivation during educational reform efforts.

As we stated in the section Personal Resources on the MATC faculty believe that, in order to successfully carry out instructional reform, teachers need to possess:

- Motivation that is fueled by a willingness to place student learning first, independent of financial rewards.
- Determination to succeed despite early implementation headaches such as:
  - Substandard equipment
  - No materials to start with

Without these personal characteristics, success would be much more difficult to achieve. A technical supervisor, explained what happens when, for instance, instructors are involved with technology for the wrong reasons.

Marco, Interviewer: Are there specific skills that faculty need to have in order get engaged in a discussion about how they want to use technology in the classroom?

Technical Supervisor: To me, the biggest one is that they value their students as opposed to doing it for themselves. They tend to be less engaged when it’s for themselves than when it’s for students. There’s one project that’s probably been going on here at the college for two and a half years, and the people involved have made very little progress. And the faculty member involved is always negotiating with the outside vendor on what his percentage will be. In my mind, that says he wasn’t learner focused.

A central administrator contrasts motivation that is not learner-centered motivation with Jeanette’s reasons for incorporating technology into her classroom.

Central administrator: We have some other people who want to use the technology just because it’s cool. I would say Jeanette has a very pragmatic view about using technology. She’s not into doing it just for the sake of doing it. She says, “OK, what can I do with this stuff that’s actually going to make what I do better?” We have no reward structure. Pay is determined strictly by union seniority basis. She’s not doing this because she’s going to get a promotion. She’s doing this because it’s something that she wants to do.
I think the rewards are more of the personal satisfaction. The Bio-Tech faculty are unique in that our lead spokespeople have Ph.D’s. They’re all high achievers in terms of their academic ability. You’d have to be, in order to remain satisfied and intellectually challenged in your position. I think that figuring out how this all fits together is an intellectual challenge. I think that those kinds of things are the drivers as opposed to just, like a said, a raise. So, individually, the biotech faculty take home work a lot more than what I see some of the other program leaders doing. They do this because they are learned and recognized and they understand what it means to stay on the top.

Another one of Jeanette’s colleagues says that Jeanette is also admired for the undaunted way in which she goes about trying new technologies.

**Becky Pearlman**, Biotechnology instructor: I think Jeanette’s colleagues see her as the technology guru in some ways because she’s brave enough to try these things out. Whereas other people might say, ‘oh, it’s going to take a lot of time,’ she’s not afraid to jump in and just try it. So people will come and ask her for advice if they’re thinking of doing something.

Jeanette herself recalls early impediments to her efforts and the extra effort she needed to put forth in order to circumvent them.

**Jeanette**: When the college stopped supporting the Windows 3.1 machines, I had to keep them going so I could continue to run the program until I got the upgrade. And I’m not great at it, believe me. So that’s very frustrating and that actually happened a couple years ago.

Some things are easy, some things are hard. Before I found Andrew Booth’s Web site (where upgraded protein purification software can be downloaded free of charge) I was looking in to hiring someone to upgrade it for Windows 95 and 98. I was going to do it through some of these grants activities we had for curriculum materials and simulation. And that’s a major amount of time and commitment. But that’s how much I liked it, and how much I think it’s important for teaching this kind of thing. But after I learned about that site, it turned out that I only needed to spend a few frustrating days downloading it.

**Discussion 5. Faculty discuss the process of getting going**

As we stated in the Getting Going section, implementing new learning technology into your classroom becomes much easier when you consult people who are already involved in the process, and when you have the support of your fellow colleagues. Jeanette begins this discussion on getting going with just that point.
Jeanette: As a program, we get along and function very well together. The program work gets done with minimum hassles and nobody gets bent out of shape about not having this or not being able to do that.

Her colleague expands on the importance of collaboration by using a personal example about his experience as program director.

Instructor: The program director is not an administrative position. It’s more of a coordinator experience. You get your fingers into a lot of different things. My philosophy on that was that I always kept everybody informed of things that I had learned, and we always made group decisions. There’s a lot of collaboration and a lot of teamwork involved in what we do in this program, and you can see it in the different activities that we do. One activity I’ve been involved with a lot the last year and a half is as an officer in the American Federation of Teachers union. Being involved in that level at the college provides me a lot of information that I bring to the group.

I’ve taught it before, and I use a lot of what Jeanette taught the last couple years. Lisa also did many of the original course preparations for all of our courses – and I built on what Lisa did because it’s a good base. It’s a real collaborative effort in that you make changes to adapt to new things and put in your own ideas. So we pick up and share things, trade back and forth all the time.

Equally important to sharing things with colleagues, is networking outside of one’s own institution. A central administrator told us about the range of ideas people can get from attending workshops.

Central administrator: We just had a workshop last week with faculty from around the Midwest who are also developing Bio-Tech programs and that was a very clear demonstration of the degree of enthusiasm that can be passed from one individual to another. Not just the idea of using the technology, but looking at the whole opportunity to reach more people at different heights.

A technical supervisor agrees with her and adds to her point by stating what he would do differently if he were to start the implementation process from scratch.

Technical Supervisor: Well, this is kind of a maverick thing. I would have gone out and done the research, said here’s what we need in terms of the technology and the resources for instruction, here’s a report, here’s the research, here’s what the majority of colleges that have had success are doing, here’s what the ones that aren’t successful are doing.

One instructor speaks about his first hand experience with this type of networking.

Instructor: Jeanette and I also went to Ireland last fall with about 30 other people from the college. We went to find out what’s going on in biotechnology
and how they train people at their local technical schools in Ireland. And we just got a smattering of information, which is really quite fascinating. And we want to learn more about it because there’s many things that we can bring back to this country.

Resource A: Institutional Context

All information in this section was excerpted from the MATC web site.

Madison Area Technical College (MATC) is the technical and community college for the greater Madison area. Founded in 1912 to teach vocational skills, today MATC is a nationally-ranked technical college. It is one of the largest of the Wisconsin Technical College System's 16 colleges and serves approximately 50,000 individuals, or about one in 12 district residents, annually. It provides a comprehensive curriculum of technical, liberal arts and sciences, adult basic education and continuing education, as well as customized employee training. The college awards associate degrees, technical diplomas and certificates and offers classes that transfer to four-year degree programs.

Approximately two-thirds of its 400 full-time faculty members hold advanced degrees. The college's annual follow-up surveys consistently report that more than 90 percent of MATC graduates are employed soon after graduation. In addition, satisfaction scores among MATC graduates and their employers routinely rate above 90 percent.

MATC provides training for more than 100 careers, including such high tech fields as biotechnology, electron microscopy, web page design and computer networking. Its varied programs include accounting, marketing, culinary trades, nursing, automotive technology, police science and welding. In addition, MATC is one of only three technical colleges in the state to offer a wide selection of liberal studies classes that transfer to four-year colleges and universities. MATC is the single largest source of students transferring to the University of Wisconsin-Madison and is one of the state's leading providers of customized training for employers.

MATC serves all or parts of 12 counties located in south central Wisconsin. Its 11 college facilities are spread among five campuses. MATC's regional campuses are located in the communities of Fort Atkinson, Portage, Reedsburg and Watertown. In addition, the college offers instruction in hundreds of locations throughout its district.

Resource B. Assignments and Exams from Jeanette Mowery’s “Protein Bioseparations” Course.

PROGRESS REPORT FORMAT

PROJECT DESCRIPTION: State what the project goals are and how those goals will be accomplished.
**MATERIALS AND METHODS:** Write a complete methods section in PAST TENSE, (not in procedure format). Organize it by sections such as “Making Crude Extract, AS precipitation, Protein Assay, Enzyme Activity assay”, etc

**RESULTS:** Include all raw data and calculations. Organize the enzyme activity and specific activity data into tables as described in the instructions in the Lab Manual, Appendix 5 for reports. This is a lot of work but you will be able to use the entire section in your final report.

**SUMMARY OF PROJECT SO FAR:** Include a table like the example below to summarize your purification thus far.

<table>
<thead>
<tr>
<th>Purification Step</th>
<th>Enzyme Units/ml</th>
<th>Protein mg/ml</th>
<th>Volume of fraction</th>
<th>Yield: Units in total volume</th>
<th>Yield %</th>
<th>Specific Activity</th>
<th>Purification Factor (Enrichment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Extract</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonium Sulfate pellet-resuspended</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dialysate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**PLAN FOR COMPLETION OF PROJECT:** Describe the remainder of the project. Include a brief general description of what you will do to accomplish your goals.
Name: _____________________

PROGRESS REPORT CRITERIA

PROJECT DESCRIPTION: Complete and Appropriate (5 points) ____________

MATERIALS AND METHODS: Complete and Clearly written (10 points):
Organized into sections

RESULTS: 20 points
Sample calculations present and accurate. ______________
Protein concentrations of each purification step present and accurate. __________
Enzyme activity of each purification step present and accurate: __________
Table summarizing purification so far is present and accurate __________
Explanatory text included, complete and accurate. __________

PLAN FOR COMPLETION (5 points) present and clearly stated.

UNDERSTANDING of the experiment or procedures is demonstrated in the report. (5 points) __________

FORM AND READABILITY: _______ (5 points) Complete sentences and correct spelling are used throughout the report. The sentences make sense and are clearly worded and easy to read. The report has been proofread.

Notes: Calculate all purification factors relative to the crude extract.

Write the materials and methods section as if your reader were a knowledgeable lab technician.

No need to say that you turned on the spec and set the wavelength at 595. Assumed that the person knows to use a spec. Dialyzer removed from plastic wrap.

Project description should not contain experimental details. It should say generally how the purification will be accomplished – a series of steps, including AS, dialysis and ion exchange chromatography.
QUIZ 1

Multiple Choice: Circle the correct answer. (2 pts each)

1. In protein purification, dialysis is useful for the following purpose  a) separation of proteins based on hydrophobicity  b) salting out of proteins  c) desalting of protein containing solutions  d) to exchange buffer solutions that the protein sample is dissolved in e) both c and d above.

2. During purification of an enzyme, specific activity should (increase, decrease) as purification proceeds.

3. The total amount of protein in your sample based on the BioRad protein assay should (increase, decrease) as purification proceeds.

4. Which of the following methods are used during the purification of beta-galactosidase to maintain protein stability. A) including dithiothreitol in purification buffers  b) keeping all protein containing solutions on ice or in the refrigerator oat all times c) adding stop solution to the enzyme assays d) maintaining the protein and its buffers at pH 4.0. d) both a and b above.

5. Which of the following is the natural substrate of the beta-galactosidase in E. Coli  (a) sidase (b) fructose (c) lactose  d) o-nitrophenol (ONP) e) ONPG.

6. The isoelectric point (pl) of a protein is a) the pH at which there is no net charge on the protein  b) the pH at which the protein will bind to an ion exchange column c) the pH at which the protein is the most soluble d) none of the above.

True/False. (2 points each) Circle T or F.

7.    T   F   It is a reasonable goal to retain all the enzyme activity that you started with during purification of that enzyme.

8.    T   F   Protein separation by ammonium sulfate precipitation is based on the fact that the solubility properties of proteins are different.

9. (4 points) Short answer: In the space provided next to the protein property below, write out a protein separation technique which is based on that property.

size (molecular weight) __________________________________________________________

charge (pl)_____________________________________________________________________

heat stability___________________________________________________________________

solubility:______________________________________________________________________
10. (3 points) This question relates to the computer purification exercise. During the course of your protein purification, you decide to run 2-D gel electrophoresis with immunoblotting to determine the purity of your sample. The following result is obtained. The protein which shows up on immunoblot is circled with dotted line. Based on the information given, the best method to remove the two contaminating proteins is probably which one of the following methods: (Assume that the stability range of your protein is not an issue)

\[
\begin{array}{cccccc}
\text{pH} & 4 & 5 & 6 & 7 & 8 & 9 \\
\hline
\text{Mr} & & & & & & \\
\end{array}
\]

a) gel filtration chromatography  
b) ion exchange chromatography  
c) heat denaturation  
d) none of the above.

11. Fill in the Blanks: (5 points)

In the space provided, write out the **best** answer for the unit of measurement for each of the terms listed below. For some terms, there may be more than one correct answer.

Volume: _____________________  
Concentration: _________________  
Weight:______________________  
Specific Activity: ____________  
Units of Enzyme activity: ________________

- microgram (\_g)  
- milliliter (ml)  
- milligram (mg)  
- nanomoles of product formed per minute at 37 degrees C  
- molarity  
- units of enzyme activity  
- mg protein
12. (4 points) If your stock solution is 0.5 mg/ml, how much of your stock do you need to make 1 ml of a 5 ml solution.

13. (5 points) You would like to test your protein extract for enzyme activity but you didn’t want to use more than 10 ml of your sample because you want to conserve as much of your enzyme as possible. You decide to test three different dilutions, 1/100, 1/500 and 1/1000. You will need 20 ml of each dilution in order to perform the enzyme assay. Explain how you would make the dilutions accurately. Assume it is not accurate to measure less than 5 ml.

14. (3 points) You are attempting to follow a laboratory protocol. It says to centrifuge the preparation for 10 minutes at 10,000 rpm in the SE-12 rotor. Because of the size of your samples, you need to use the GSA rotor instead of the SE-12. How would you modify the protocol for your samples. Use the table.

15. (10 points total) In the process of your beta-galactosidase protein purification, you want to determine the specific activity of your extract. You decide to perform the BioRad protein microassay protocol just as written in your lab manual. You dilute a sample which contains your protein 1/20 in order to perform protein and enzyme assays. You take 20 ml of the diluted sample and add 780 ml of water just as it states in your lab manual protocol. You then add 200 ml of the Coumassie blue dye and measure the absorbance as directed.

<table>
<thead>
<tr>
<th>mg protein of standard</th>
<th>Absorbance at 595nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8</td>
<td>0.055</td>
</tr>
<tr>
<td>4.0</td>
<td>0.241</td>
</tr>
<tr>
<td>8.0</td>
<td>0.442</td>
</tr>
<tr>
<td>16.0</td>
<td>0.846</td>
</tr>
<tr>
<td>20.0</td>
<td>0.993</td>
</tr>
</tbody>
</table>

Absorbance at 595nm of diluted extract (1/20 dilution) - 0.632

a) Use the graph paper provided to make your standard curve.

b) What is the concentration of total protein in the diluted sample in ml.

c) What is the concentration of total protein in the original sample in mgs/ml.
d) If your original sample had a total volume of 5 ml, what is the total amount (weight) of protein you have.

e) If the enzyme activity of the undiluted sample is 500,000 units/ml, what is the specific activity of your beta-galactosidase?

16. BONUS: (3 points) Why does 1M Na₂HCO₃ stop the activity of beta-galactosidase?

TAKE HOME EXAM: 150 points

1. You have been given a project to improve the purification protocol for an enzyme, MATCase, which has great potential benefit for the agricultural industry in Wisconsin. Toward this goal, your first assignment is to determine the specific activity of a partially purified enzyme fraction from a previous purification attempt. You go to the –70 freezer, box labeled “MATCase purification”, and remove an aliquot labeled “semi-purified MATCase, approximately 0.35 mgs/ml”. Your supervisor has indicated that you should not be satisfied with any labeling left by the previous person and wants you to repeat the protein determination.

a) 20 points. Outline the steps you would need to do in order to perform the BIORAD protein microassay procedure and determine the protein concentration of your enzyme sample. Assume that the solvent is water and that you can use bovine serum albumin as the standard protein (comes from Sigma as a powder). How would you make the stock standard solution, set up standard dilutions for standard curve, make dilutions of the enzyme fraction, etc.

<table>
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<tr>
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<td>5</td>
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</tbody>
</table>

b) 20 points. You did the specific activity determination on the previous MATCase preparation and it was worse than the crude extract and even worse than your supervisor had feared. She now wants you to design a purification scheme for this enzyme. You spend some time asking questions about the previous work and list additional characteristics of the enzyme:

pH stability- 6.5-9.5
pl – not known
temperature stability – stable to 45°C for short periods (ten minutes) of time
Maintains good activity in TRIS buffers.
Enzyme assay- enzyme kinetics well understood by biochemistry people with company – assay works well.

Outline a strategy to purify this enzyme. (There isn’t only one answer- many possible good answers) How would you go about finding properties and behaviors of this protein which would help you?
2. 5 points. Explain why it is most accurate to do a standard curve each time you want to determine the value of an unknown when using a colorimetric assay (dye based) like the BIO-RAD.

3. 5 points. If you perform the Bio-RAD protein assay and one of your unknowns is too concentrated to read in your standard curve, would it be appropriate to dilute that sample so that it will lie within the linear range? Yes or No. Explain why or why not.

4. 10 points. It's Friday afternoon and someone used the last of the enzyme assay buffer. Life is hard but you have to make some more. One of the components in the recipe is 0.5 gms of MgCl₂. When you go to the shelf, you find only MgCl₂·6 H₂O. How would you make the substitution? Show all work. Circle answer.

5. 5 points. How many grams of NaCl are in 250 l of 2.5 mM NaCl.

6. 5 points. How many millimoles of NaCl are there in 10 mls of a 45% solution?

7. 5 points. If you make a 1/1000 dilution of your beta-galactosidase in order to assay the enzyme activity and it turns bright yellow immediately after adding the ONPG, would this assay be accurate? Explain your answer. What would you do about it. How would you choose the dilution factors and how would you make this dilution or dilutions. Assume that you want to use as little of your precious enzyme sample as possible.

8. If you need to make some NTM buffer with 0.3 M NaCl, can you dilute NTM buffer with 0.4M NaCl with water in order to make NTM with 0.2. Explain why or why not?

Can you make 0.3 M NaCl

Can you make 0.32 M NaCl. Explain your reasoning.

9. Explain why ammonium sulfate is most often used for salting out procedures.

10. You have just been given a lab project to modify the enzyme assay protocol for measuring the activity of beta-galactosidase using ONPG as substrate. The
volumes must be adjusted for a new spectrophotometer with very small cuvettes. How will you modify this assay so that the total assay volume is 0.5 mls.

How would you re-design the assay if you want to make sure that the enzyme has the same number of moles of substrate available as in the larger volume assay. Show all work.

What the conversion factor be 380 or would it change? What would it be? Explain your reasoning?

What is the wavelength for enzyme assay? Why?

What is the wavelength of the Biorad assay? Why?

Why do we measure the Absorbance at 280 for our fractions off the ion-exchange column?

How does Na₂CO₃ function as a stop solution for the beta-galactosidase assay?

11. 5 points. During beta-galactosidase purification, what if you made a mistake during the beta-galactosidase purification and used 0.4 M NTM buffer instead of 0.2 M NTM buffer to dialyze your sample. What would be the result of this mistake when loading your dialysate on the DEAE ion-exchange column? What could you do to correct this mistake?

12. 20 points. The following table documents the results of a protein purification procedure. Fill in the table below:

<table>
<thead>
<tr>
<th>Purification Step</th>
<th>Enzyme Units/ml</th>
<th>Protein mg/ml</th>
<th>Volume of fraction</th>
<th>Units in total volume</th>
<th>Yield %</th>
<th>Specific Activity</th>
<th>Purification Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude</td>
<td>100,000.00</td>
<td>20.0</td>
<td>40 ml.</td>
<td></td>
<td>100</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Ammonium Sulfate pellet-resuspended</td>
<td>100,000.00</td>
<td>10.0</td>
<td>10 ml.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dialysate</td>
<td>70,000.00</td>
<td>3.5</td>
<td>12 ml.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ion Exchange</td>
<td>7,000.00</td>
<td>0.35</td>
<td>4 ml.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b) Discuss the results of this purification? How successful was this purification attempt? Did specific activity and yield change in the expected manner at each step? What modifications would you make in your purification process next time based on the results in this table?
13. 10 points. The following questions concern analysis of yield during enzyme purification.

a) If you have 0.5 ml of an enzyme solution containing 200 units/ml, how many units do you have?

b) If you have 10mls of a solution containing 200 units/ml, how many units do you have?

c) When comparing the percent yield from one purification step to the next (say between crude extract and ammonium sulfate pellet), is it useful to express the enzyme activity in units/ml if the volumes are not equal. Explain. Why or why not? If answer is no, what is an alternative way to express the units in order to compare the yield.

14. 10 points. You would like to solve the world’s garbage and landfill problems and maybe make some dollars for yourself along the way. After years of research in the field, you have isolated very small amounts of an enzyme, garbagase, that degrades a type of plastic that is used in many throwaway containers (as well as the plastic in trashbags and disposable diapers). You have been able to produce a reliable antibody and work out the conditions for a reliable enzyme assay. However, this enzyme is only found in very small quantities, produced by a rare species of fungi only when in the presence of a really foul and toxic (to humans) compound. This compound apparently induces the expression of this enzyme. You decide to clone this enzyme in E. Coli so that it is produced constitutively (doesn’t need toxic compound for expression). After many attempts, you succeed in cloning the enzyme. The recombinant enzyme has the same molecular weight as fungal enzyme and is recognized by the antibody to fungal garbagase.

15. 20 points. You want to determine the amount of total protein in your 50 mls of crude extract. You set up standards for the BioRad microassay. You dilute an aliquot of the crude extract 1->10. You then remove 20 _l of the diluted crude extract for assay, adding 780 _l of H20 and then 0.2 of Bio Rad dye reagent. 15 minutes later, you read the OD at 595 nm and determine that there are 2 ug in the tube that you assayed.

a) What is the protein concentration of the original sample in mgs/ml
b) What is the specific activity of the crude extract if the original sample has 15,000 units/ml.
c) How much protein do you have in the entire volume of crude extract.
Resource C. Methods used to produce this case study

Marco Molinaro and Flora McMartin, researchers for the Institute on Learning Technology conducted interviews and observed labs and classrooms during February, 2001. Andrew Beversdorf also conducted a follow up interview with Jeanette Mowery in June, 2001 at the Madison Area Technical College (MATC).

In all, we interviewed four instructors in the Biotechnology Laboratory Technician Program, a technical supervisor, and a central administrator.

The interviews were guided by the protocols used in all the Learning Through Technology case studies and were taped and transcribed. Andrew Beversdorf analyzed the interview material, and with help from Susan Millar, as well as from Sharon Schlegel and Mark Connolly, produced this case study.

Glossary

**Assay**—A test to find out whether or not a particular protein is contained in a solution.

**Immunoblot**—A test that shows how much of a particular protein is present in a solution. During an immunoblot, a specific antibody that only reacts with the target protein is injected into a solution. When the lab technician finds the reaction, she knows how much of the target protein she has.

**Learning Environment**—A learning environment is a place where learners may work together and support each other as they use a variety of tools and information resources in their pursuits of learning goals and problem-solving activities (Wilson 1995).

**MATC**—Madison Area Technical College.

**Track**—A term used in conjunction with the web site “Trackstar,” it is an organized, annotated compilation of web sites that focus on a single theme (See Becky Pearlman’s, MATC Molecular Biology Professor, track “DNA Fingerprinting and Bioinformatics”[41]), often used as an online lesson.

References


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[41] Becky’s track can also be accessed by going to the Trackstar homepage (http://trackstar.hprtec.org/) and doing a keyword search for DNA Fingerprinting and Bioinformatics.
