Flipping the Microbiology Laboratory to Improve Student Preparation and Increase Student Interaction

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Summary

To make the most efficient use of the limited time available in the microbiology teaching laboratory we redesigned the course to incorporate online lectures, video demonstrations and quizzes to be completed outside the laboratory. We predicted this “flipped” laboratory model would improve student preparation and increase student interactions leading to an improved learning environment. The primary tool for assessing the learning environment was a survey instrument developed by Fraser (Fraser 1998). Students completed a pre- a post-survey of the learning environment. Based on the results of the survey, student perception attitude toward laboratory exercises improved after completing the course. Observations of student preparation and interaction showed that students came to the laboratory prepared and were able to complete laboratory project during the allotted time period. Students were able to work more independently and helped each other rather than always seeking help from the course instructors.

Purpose of the project

Because of limited space in teaching laboratories, increased enrollment must be met with an increased number of laboratory sections, creating constraints on the amount of time that can be spent in the laboratory. A significant amount of valuable laboratory time is spent on background information and demonstration of techniques which can easily be presented online prior to the class meeting. This approach to course design is often referred to as the “flipped” or “inverted” classroom (Lage, 2000). Online presentations not only free up valuable laboratory time but also enable students to effectively prepare for laboratory activities, increasing their confidence in performing laboratory techniques. The use of the flipped classroom format creates several challenges, particularly with respect to student expectations and the classroom learning environment (Gannod et al 2008 and Stryer 2007). Student attitudes appear to be influenced by the structure of the learning environment and the variety of learning activities in which they are engaged (Stryer 2007). In the traditional laboratory course, a common complaint is about confusion regarding particular techniques and the inability to observe techniques up close leading to frustration as they try to complete the necessary tasks. In this context, the “flipped” classroom approach can reduce student confusion and create a more comfortable learning environment for the student. In addition to the improved learning environment, online preparation can reduce inconsistency in presentation of the material when there are multiple laboratory sections. Having students in all laboratory sections read laboratory protocols, watch video demonstrations and take pre-laboratory quizzes will enhance student preparation by presenting a consistent and thorough training. Lastly, if students are better prepared the instructor will be able to spend more time working with students who require one-on-one assistance or discussing student observations and conclusions.

In this project, a pre- and post-course survey instrument developed by Fraser (Fraser 1998) was used to assess the learning environment with a focus on student perception and attitudes.

Methodology

In the initial phase of the project, prior to each new laboratory exercise, students were advised to read detailed protocols, read a background PowerPoint presentation and watch video demonstration of specific techniques required to complete the activity. Each student was required to complete a short quiz addressing specific aspects of the techniques or important background information. Quizzes consisted of five questions and were required to be complete prior to beginning the laboratory activity. At the beginning and end of the course, students were surveyed for their attitudes toward laboratory courses in general and the microbiology laboratory course specifically.

While piloting the course prior to selecting the appropriate survey instrument it became readily apparent that the revised approach would also require a more significant restructuring of the course. The traditional organization of multiple individual activities that introduced important microbiological techniques was extremely confusing for the students and led to a poor understanding of why the techniques are important and how they are used in a typical microbiology research or clinical laboratory. Techniques were not taught in any context so students retained little information and could not apply the techniques in specific contexts. Therefore, before employing the survey instrument, the course was restructured into a project based course in which all appropriate techniques are introduced within the context of specific projects.

The final, project based course structure is divided into three modules. Each module focused on a group research project in which the student developed their own research questions, methodology and experimental approach. Video lectures are organized into related groups of techniques (culturing, sampling, microscopy, types of media, biochemical tests, molecular biology, etc.) Each group of activities has an introductory lecture and several demonstrations. Students can watch any and all techniques at any time. After developing a hypothesis, students develop an experimental approach to test their hypothesis, choosing techniques from the laboratory manual and available video lectures and demonstrations. Students maintain a written laboratory manual that is graded at the end of each module. After collecting their data students prepare a laboratory report either in manuscript formation or as a poster. For the posters, the students also prepare an oral presentation.

At the beginning of the course, students complete the Fraser classroom environment survey instrument based on their prior experience in laboratory courses. At the end of the course, students complete the same survey to assess any changes in perception and attitude towards laboratory courses.

Results

During a pilot study, we observed a decrease in student frustration and increased student-student interaction. Students came to class better prepared and ready to discussion what needs to be done in each laboratory period. Students more frequently asked each other questions and were better able to help other students. It also revealed the limitations of the traditional organization of the course and many of the sources of confusion for the students. With the structure of the pilot study it was easy to observe the source of much of the students' confusion. The course was focused on the exercises themselves and not on how and why the techniques are used. Because the focus was on the exercised there were numerous overlapping activities in which some days students were starting new exercises before completing others. Using the "flipped" classroom model, it was now possible to restructure the course to a project based course in which students learned the same microbiology techniques as the traditional course but in the context of independent projects which were more engaging and relevant to the student. This new structure provided more student input in their own learning, created multiple opportunities to incorporate different modes of communication (lab reports, student posters and presentations) and self and peer assessment.

The results of the pre- post-surveys are presented as Tables 1 – 5. 27 of 42 students completed the pre-course survey and 14 or 42 students completed the post-course survey. Post-course surveys were sent at the end of the semester and that may have had an impact on the reduced completion rate. The questions are grouped into 5 categories and address different aspects of learning in the laboratory – learning about the world, learning about science, learning to speak out, learning to learn and learning to communicate. Several of the questions address aspects of the course which should not be affected by the revised course structure and serve as internal controls. The most significant increases in the post-survey questions appear in the category of "Learning to Learn" (Table 4) and reflect the inquiry based nature of the course in which students take an active role in their own learning. Informal conversations with students indicate a more positive attitude towards their laboratory courses when then feel empowered to plan their own experiments. Students also showed a greater understanding of the techniques they are using because they selected the techniques themselves to accomplish a specific task. Significant improvements were also seen in the category of "Learning about the World" (Table 1). Specifically questions 2 and 6 which also reflect the inquiry based aspect of the course. By planning and carrying out their own experiments they develop a stronger connection between what they are learning in the laboratory and the world around them. Very little improvement was observed in the category of "Learning about Science" (Table 2). This is not surprising because the laboratory is more focused on the application of the science and communication rather than scientific content. Significant improvements in the category of "Learning to Speak Out" (Table 3) were only seen with a couple of questions which reflect the open nature of the course in which students are taking an active role in their own learning and being allowed to challenge the learning environment. Surprisingly, significant improvements are not seen in the final category of "Learning to Communicate". With the emphasis of the new structure on various ways to communicate science, greater improvement was expected. However, the pre-course numbers are already quite high and the limited improvement may simply reflect the fact that students have significant exposure to various methods of scientific communication prior to taking this course.

During the course of this project I have had numerous opportunities to disseminate the process and results of the work. At the beginning of the project, I presented an outline of the project at the American Society for Microbiology Conference on Undergraduate Education in Denver, CO in May 2013. The feedback received after that presentation introduced me to additional options for organizing the course and various assessment options and helped to refine the course structure. The preliminary results of the project were presented at the 2014 Missouri S&T Teaching Technology Conference. I also had the opportunity to present the project to the Missouri S&T Board of Trustees and to participate in a panel discussion on the "flipped" classroom hosted by CERTI/EdTech.

Conclusions/Future Implications/Future Dissemination

This project has provided a solid foundation for justifying the redesign of the microbiology laboratory course. The results of the survey indicate the redesign is accomplishing many of the goals that were initially established but it is clear that the survey instrument used is somewhat limited and the impact of the course redesign goes well beyond the original hypothesis. Additional assessment tools need to be found and implemented to address the many apparent improvements observed. A more robust set of assessment instruments will be needed to measure the various learning gains observed in the course.

Discussions with students and with faculty colleagues suggest the "flipped" model is a very attractive approach to more efficiently use limited laboratory space and time. It seems clear that the course redesign is having positive benefits on the student learning experience but more data is needed to support these claims.

The results of the project will be presented at the Digital Transformation Conference in San Francisco, CA September 11 and 12, 2014. I am continuing to revise the course and assessment tools in Fall 2014 and an abstract will be submitted for presentation of a poster at the 2015 American Society for Microbiology Conference on Undergraduate Education. Once sufficient data is obtained, funds will be sought to participate in the Biology Scholars Writing Residency Program to assist in preparing a manuscript for submission to the Journal of Microbiology and Biology Education.

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Table 1. Learning about the World.

#	Question	Pre Avg	#	Post Avg	#
1	I learn about the world outside of school.	3.19	27	3.79	14
2	My new learning starts with problems about the world outside of school.	2.74	27	3.79	14
3	I learn how science can be part of my out-of-school life.	3.41	27	4.14	14
4	I get a better understanding of the world outside of school.	3.41	27	3.86	14
5	I learn interesting things about the world outside of school.	3.48	27	4.21	14
6	What I learn has nothing to do with my out-of-school life.	2.63	27	1.71	14

Table 2. Learning about Science

#	Question	Pre Avg	#	Post Avg	#
1	I learn that science cannot provide perfect answers to problems.	3.93	27	4.00	14
2	I learn that science has changed over time.	4.52	27	4.64	14
3	I learn that science is influenced by people's values and opinions.	3.52	27	3.57	14
4	I learn about the different sciences used by people in other cultures.	2.63	27	3.00	14
5	I learn that modern science is different from the science of long ago.	4.07	27	4.36	14
6	I learn that science is about creating theories.	3.63	27	4.00	14

Table 3. Learning to Speak Out.

#	Question	Pre Avg	#	Post Avg	#
1	It's OK for me to ask the teacher 'Why do I have to learn this?'	2.67	27	3.57	14
2	It's OK for me to question the way I'm being taught.	2.41	27	3.64	14
3	It's OK for me to complain about teaching activities that are confusing.	2.38	27	3.00	14
4	It's OK for me to complain about anything that prevents me from learning.	2.89	27	3.93	14
5	It's OK for me to express my opinion.	3.59	27	4.00	14
6	It's OK for me to speak up for my rights.	3.73	27	4.21	14

Table 4. Learning to Learn

#	Question	Pre Avg	#	Post Avg	#
1	I help the teacher to plan what I'm going to learn.	1.67	27	3.21	14
2	I help the teacher to decide how well I am learning.	2.07	27	3.14	14
3	I help the teacher to decide which activities are best for me.	1.56	27	2.93	14
4	I help the teacher to decide how much time I spend on learning activities.	1.70	27	2.64	14
5	I help the teacher to decide which activities I do.	1.44	27	2.71	14
6	I help the teacher to assess my learning.	2.04	27	3.00	14

Table 5. Learning to Communicate

#	Question	Pre Avg	#	Post Avg	#
1	I get the chance to talk to other students.	4.07	27	4.71	14
2	I talk with other students about how to solve problems.	3.93	27	4.43	14
3	I explain my understandings to other students.	3.89	27	4.43	14
4	I ask other students to explain their thoughts.	3.52	27	4.36	14
5	Other students ask me to explain my ideas.	3.63	27	4.14	14
6	Other students explain their ideas to me.	3.65	27	4.00	14