How We Flipped: Student and Instructor Reflections of a Flipped-Class Model in a Sensory Evaluation Laboratory Course[1]

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Abstract

The flipped class model was explored in a Food Science and Human Nutrition course on the Sensory Evaluation of Foods. The laboratory associated with this course was changed to fit the new lecture structure. In the laboratory, nine groups of students (n=54) were given different food categories and scenarios that guided them through three categories of sensory testing. Students designed, executed and analyzed their own sensory tests to reinforce lecture concepts. Upon course completion, students completed confidential instructional surveys related to the course. Student surveys indicated that the laboratory directly reflected lecture content, allowed for a majority of group project to be completed within the class setting and enhanced student learning through the integration of lecture knowledge with hands-on experience. Instructor reflections revealed that the active learning fostered in the laboratory contributed to the positive student experiences. Instructor reflections on course design, teaching approaches and challenges faced in the development of course materials were explored, resulting in further proposed improvements to the course by reorganizing selected content and optimizing group structures to better suit student needs. Principles of the flipped class model were demonstrated to successfully be used to redesign a corresponding laboratory section to increase student engagement and active learning.

Introduction

Despite pedagogical innovations, traditional lectures that remain focused on lecturer-delivered facts rather than student-focused understanding continue to dominate the educational system (Bligh, 2000; Butt, 2014). Blended learning, one of the pedagogical innovations, is broadly defined in the literature as learning that incorporate the use of online materials to enhance or partially replace traditional in-classroom lectures (Baker, 2000; Garrison and Kanuka, 2004; Picciano, 2006; Graham, 2006; Allen et al., 2007; McGee and Reis, 2012).

The flipped or inverted classroom is a form of blended learning (Garrison and Kanuka, 2004). First explored by Baker (2000) and Lange et al. (2000), this model focuses on in-class discussions and activities that create active learning environments, where students engage in higher order thinking processes (Garrison and Kanuka, 2004; Prince, 2004; Roehl et al., 2013). The flipped classroom accomplishes this by placing traditional lecture notes and information outside of the classroom, typically online, in the form of videos or other supplemental material. Students are then free to review online lecture videos to grasp foundational concepts before attending lecture. By doing this, classroom time becomes dedicated to group work, discussion and problem-solving activities related to the content students previously viewed (Tucker, 2012; Herreid and Schiller, 2013).

Research concerning the benefits to student learning by the flipped classroom model has been shown in various disciplines such as nutrition/dietetics (Gilboy et al., 2015), engineering (Warter-Perez and Dong 2012), microbiology (Lage et al., 2000), business (Butt, 2014), architecture (Zappe et al., 2009) and others (Herreid and Schiller, 2013; Roehl et al., 2013; Hawks, 2014). Specifically, the benefits associated with active learning in science, technology, engineering and mathematic (STEM) courses include increased examination scores and decreased likelihood of course failure (Freeman et al., 2014). Fostering active engagement, a cornerstone of the flipped classroom model, in clinical settings where competency in skill application is required, has improved standardized test scores and student content understanding (Everly, 2013). The creation of settings, such as laboratories, where students further utilize the knowledge gained in a flipped classroom can help to supplement the topics explored during lecture.

A traditional undergraduate course in the Food Science and Human Nutrition department was restructured to fit the flipped classroom model. With the

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classroom flip, a need arose to completely restructure the course's corresponding laboratory section. The laboratory flip involved an emphasis on student-directed laboratory process that aligned with the group project assignments occurring in the classroom, rather than instructor-directed laboratory exercises. The two primary objectives of this study were to (1) assess student perceptions of a restructured laboratory that built upon the concepts learned in the flipped classroom and (2) reflect on instructor perceptions related to the course redesign, restructure and implementation of the flipped laboratory.

Methods and Materials

Course Background

Sensory Evaluation of Foods (FSHN 302) is a required course for all undergraduate students majoring in Food Science and Human Nutrition (FSHN) at the University of Illinois at Urbana-Champaign (UIUC). This course consisted of 50 undergraduate juniors and seniors who participated in online (two, 10-minute lecture videos), in class (one hour, lecture/discussion twice a week) and laboratory (two hours, once a week) activities. The students were divided among the three laboratory sections with a maximum of 18 students per section.

Laboratory Structure

The focus of the flipped classroom and laboratory was a semester-long group project. Within each lab, students were divided into three groups of six and were assigned a given product category and initial scenario. These product categories and scenarios covered topics and challenges pertinent to the food industry. Students remained within the same product category throughout the semester; however, the scenarios they were presented with were dynamic. The scenarios changed to fit each section of the course as the semester progressed. The products and scenarios can be found in Table 1.

In this flipped classroom, online lectures and in-class discussions directly related to laboratory activities. For example, as shown in Table 2, lab six was focused on reference generation and refinement for the descriptive analysis method of sensory testing. At the same time in the online lectures, students watched videos highlighting the methods of descriptive analysis used in the industry and how each of these methods generate and refine references. In-class activities focused on generating attributes, references and definitions in their respective groups so the students could get accustomed to this process. This general design was followed for all lectures and laboratories throughout the semester.

At the start of each laboratory, learning objectives directed students to complete a set of activities. The laboratory manual used by students provided a general framework and guidance for students on how to complete the main objectives of each lab. These activities led students to design, conduct and analyze three major classifications of sensory tests: discrimination testing, descriptive analysis and consumer testing. The activities associated with each laboratory session are listed in Table 2.

During laboratory lessons, teaching assistants (TAs) assumed the role of a "guide on the side" (King, 1993). The TAs' job during the laboratory was to facilitate stu-

Table 1: Product categories and scenarios presented to groups based on the type of sensory test being conducted

Product category	Scenario 1: Discrimination testing	Scenario 2: Descriptive analysis	Scenario 3: Consumer testing
Ketchup	Due to an effort to reduce sodium across products, your company has produced a reduced sodium ketchup. Investigate if sensory differences between the original and variant product exist.	Investigate all sensory modalities that distinguish your original and variant product	With an improved product based off of difference and descriptive data examine consumer perceptions between your original, variant, improved, and a competitor's product
Vegetable juice	With a desire to improve fiber content, your company has developed a high fiber tomato juice. Investigate if sensory differences between the original and variant product exist.	Same as above	Same as above
Cookies	Your company is interested in developing a reduced fat cookie. Investigate if sensory differences between the original and variant product exist.	Same as above	Same as above
Gum	To keep up with current health trends, your company wishes to develop a nutrient enhanced gum. Investigate if sensory differences between the original and variant product exist.	Same as above	Same as above
Ice cream	In an effort to reduce fat content across your portfolio, your company has developed a fat free ice cream. Investigate if sensory differences between the original and variant product exist.	Same as above	Same as above
Canned peaches	Due to the high sugar content of your products, your company has altered the sugar content of their canned peaches. Investigate if sensory differences between the original and variant product exist.	Same as above	Same as above
Gluten free bread	In response to market trends, your company has developed a gluten free bread. Investigate if sensory differences between the original and variant product exist.	Same as above	Same as above
Granola bars	To increase protein content of their granola bars, your company has produced a high protein granola bar. Investigate if sensory differences between the original and variant product exist.	Same as above	Same as above
Chips	In response to a concerns regarding fat content, your company has developed a fat free chip. Investigate if sensory differences between the original and variant product exist.	Same as above	Same as above

Table 2: Laboratory weekly objectives based on course section and example activities performed in each laboratory

Laboratory session	Section of course	Laboratory objective	Example activities
1	Introduction	Getting to know the course	Course expectations; using course website; lab report formatting; library resources tutorial; self-questionnaire
2	Discrimination testing	Design and plan discrimination test	Introduction to discrimination testing; develop rinse protocol; choose testing method; ballot design; organizing applicable materials
3		Conducting the discrimination test	Sample preparation; test set-up; panelist briefing; cleanup
4		Statistical methods and results analysis	Brief lecture on statistical analysis using Excel; example exercises; group work to analyze data
5	Descriptive analysis	Panel introduction and screening	Introduction to descriptive analysis methods; roles of panel leader and panelist; panelist screening demonstration
6		Reference generation and refinement	Initial generation of sample terms, definitions, and references as an individual and a group; refinement of terms, definitions, and references
7		Attribute scaling and intensity rating	Reference scaling individually and as a group; final choice for attribute intensity scores
8		Statistical methods and results analysis	Brief lecture on statistical analysis using Excel; group work to analyze data
9	Consumer testing	Design and plan consumer test	Introduction to consumer test methods (acceptance, preference); choosing test questions and design; ballot design; creating recruitment materials; choosing test location
10		Consumer test preparation	Preparing testing materials (ballots, cups, labels, etc.); solidifying test logistics
11		Conducting the consumer test	Conducting test in public location
12		Statistical methods and results analysis	Brief lecture on statistical analysis using Excel; group work to analyze data
13		Additional statistical analysis	Brief lecture on statistical analysis using Excel; group work to analyze data

dents' interaction with the course material; guiding them to utilize what they learned through lectures and online videos to complete the tasks associated with the laboratory. For example, as shown in Table 2, laboratory session 2, students were required to choose a discrimination testing method to use. Students previously watched online videos and participated in lecture discussions about the many types of discrimination tests. It was their choice, not the TAs, to decide what type of test was most appropriate for their sample. They then went on to develop ballots to use, sample rinse protocols and later conducted their selected discrimination test (lab 3), analyzed their results (lab 4) and presented their findings during the in-class lecture. Despite the great amount of work associated with each laboratory, sessions were designed to not occupy the entire two hour time frame. Instead, students were encouraged to use the remaining time to complete upcoming assignments that were due such as lab reports, group assignments and presentations.

Student assessment in this course was done through the completion of group project questionnaires that were designed with three major goals in mind: synergizing information presented during in-class and online lectures with the laboratory at hand, preparing students for the test occurring and probing students to investigate further into their area of investigation using scientific literature.

Students also prepared a single written lab report and PowerPoint presentation based on their findings for each sensory test category section of the course.

Student Course Evaluations

The UIUC institutional review board (IRB) reviewed the study protocol and materials used in the assessment of this course and deemed it exempt under 45 CFR 46.101(b) (1). All participants provided written informed consent prior to any participation in course evaluations. Informed consent was collected without the presence of the instructor TAs. This was done so that instructional staff had no knowledge of the students who would participate in the survey. Instructors and TAs were not granted access to these consent forms until final grades were submitted.

A confidential (no registration required) online survey developed by the course instructor was administered to all students via Survey Monkey at the completion of the course. The survey consisted of multiple choice and open-ended comments covering the laboratory and lecture. Of all the students registered for the course (n=54), fifty total students provided informed consent and completed the online survey.

Results

Online Survey Multiple Choice Responses

Survey questions pertaining directly to the laboratory section of the course are the only discussed in this publication. Responses were tallied and percentages calculated from responses to individual questions downloaded directly from the online survey. These tallies and percentages are presented in the Tables 3 and 4. Using Microsoft® Excel® 2013 (Version 15.0: Redmond, WA) the one-way chi-squared test was conducted on tallied student responses for the two investigated questions to determine significant differences. Significant differences ($p<0.05$) among the student responses were observed for the question, "how much do you agree with the statement: the material covered in lab directly reflects what is taught in lecture?" Response tallies in Table 3 indicated that a majority of students (n=45) strongly agreed that the course materials covered in lab directly reflected the materials covered in lecture. Significant differences ($p<0.05$) among the student responses were observed for the question, "on average, how much of the group project do you feel your group is able to complete during lecture and lab time." Response tallies in Table 4 indicated that a majority of students (n=29) completed 60% or more of the group project work for the class during lecture and lab.

Table 3. Student Responses Regarding the Value of Equine the Industry Internships (n=13)[z]

Possible responses	Tallied responses	Response percentage (%)
Strongly disagree or disagree	4	8
Neither agree or disagree	1	2
Strongly agree or agree	45	90

Table 4: Student responses to the online survey question, "On average, how much of the group project do you feel your group is able to complete during lecture and lab time?" (n=50)

Possible responses	Tallied responses	Response percentage (%)
100-80%	10	20
79-60%	19	38
59-40%	14	28
39-20%	7	14
20-0%	0	0

Online Survey Open-ended Student Responses

One open-ended survey question pertaining directly to the laboratory was incorporated as part of the online survey. Student responses were collected directly from the online survey and are shown in Table 5. Comments are presented as students reported them, however, some were edited for grammatical mistakes. In an effort to more succinctly visualize student comments, each comment was summarized into key phrases that described the comments content. Summarized key phrases can be found in Table 5. These key phrases were also visually represented in a word cloud (www.wordle.net) in Figure 1. In this qualitative, visual representation of data, key phrases more frequently reported are represented by larger font sizes. Based on observed trends in Table 5, these key phrases were, then, placed into one of four categories: (1) time allocation, (2) general impressions, (3) general learning, (4) active learning and (5) general structure. The comments falling into each of these categories were then tallied. These categories, examples of the key phrases that went into each category and the tallies for each category are presented in Table 6.

Discussion

Student Reflections

The online survey probed many questions surrounding the lecture and laboratory sections of this course, however, asked far more questions regarding the material developed for the lecture (videos, quizzes, etc.). Despite the limited amount of questions asked regarding the laboratory, much information regarding the course can be devised from the valuable student comments and answers to the two multiple choice questions addressed in Tables 3 and 4.

In regards to Table 3, the question addressing if laboratory material directly reflected lecture content, a majority of students (90%) strongly agreed with the statement that it did. This indicated that students saw a strong connection between the content addressed in the lecture and the practical applications incorporated in the laboratory. This was seen as a positive outcome as the utilization of learned content in the form of active learning has led to improved scores in the classroom and on standardized tests (Everly, 2013; Freeman et al., 2014). This course was purposefully designed by the instructor and TAs to allow students to see the connection and

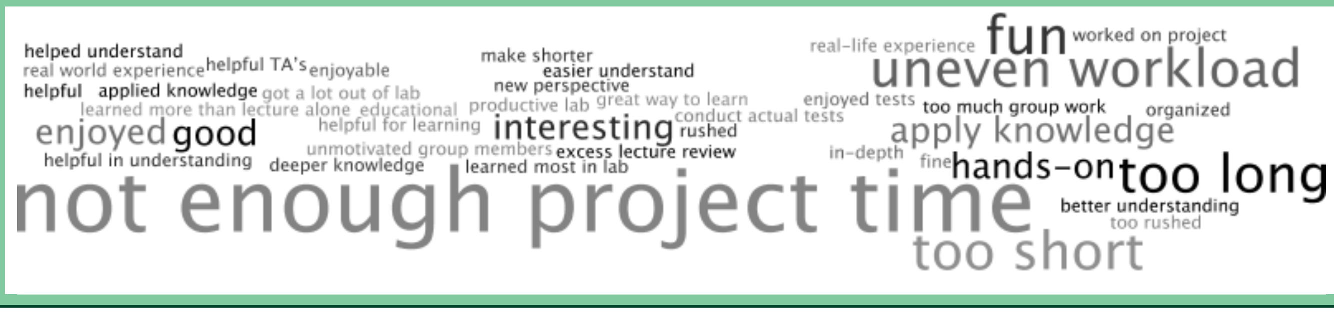
Table 5: Student survey responses to the open-ended question, "please provide any general feedback in relation to the laboratory sessions not covered in the survey"

	Key phrases
Some labs are too long.	Too long
Some labs we had less things to do and others we couldn't finish.	Uneven workload
Sometimes too long.	Too long
Labs were good except when we were crammed on time (DA lab).	Good; too short
Some lab sessions felt rushed and others too slow	Uneven workload
Laboratory sessions were good, fun and educational.	Fun; educational; good
I really enjoyed the lab sessions. They taught most of what I learned. I like doing the tests and felt that helped my understanding.	Enjoyed; learned most in lab; helped understand
Lab was rushed some days and made it challenging.	Rushed
I got the most out of this class from my lab experiences. They were a hands on approach that explained things more in depth.	Hands-on; in-depth; got a lot out of lab
The laboratory sessions were organized and enjoyable, however, some were crunched for time.	Organized; enjoyable; too short; uneven workload
I was able to apply what we were doing in class and experience how hard it actually is to be a panelist and a scientist.	Apply knowledge; real world experience
They were fun, interesting, and very helpful.	Fun; interesting; helpful
If you want to do more work in lab to include the lab itself as well as group work, I would suggest making lab an hour longer.	Too short
I really liked being able to conduct actual tests on one product throughout the entire semester. I feel that I learned a lot more by actually conducting the test than if we had only learned in lecture.	Enjoyed; conduct actual tests; learned more than lecture alone
Wish to have more time to work on group project.	Not enough project time
Sometimes we did not get enough time to work on group projects.	Not enough project time
Lab was fine, very helpful for learning about the specific test and analyzing our product. Some lab sessions could have been shorter.	Fine; helpful for learning; make shorter
I applied my knowledge and I got a better understanding of what I learned.	Applied knowledge; better understanding
The labs were interesting and going through similar processes and protocols as sensory scientists gave a new view on sensory science.	Interesting; real-life experience; new perspective
Some labs were far too rushed. Many times it was great to work on the project and be able to ask questions to the helpful TA's.	Too rushed; worked on project; helpful TA's
I liked running our own sensory tests but there was too much group work involved. Sometimes people don't participate and it makes the project stressful. We didn't have enough time to work on lab reports and presentations in lab.	Enjoyed tests; too much group work; unmotivated group members; not enough project time
More time on group work and less on reviewing lecture topics	Not enough project time; excess lecture review
They are helpful because we apply what we learn, making it easier to understand the material. My group got a lot of work done in lab	Apply knowledge; easier understand; productive lab
I wish we had more time to work on lab reports in lab.	Not enough project time
Lab was very helpful in understanding the hands-on portions of the class and getting a deeper knowledge of in class topics.	Helpful in understanding; hands-on; deeper knowledge
Labs are fun and a great way to learn class material.	Fun; great way to learn
Almost too much time was given. Lab can be shorter.	Too long

Table 6: Category tallies of key phrases derived from open-ended student comments to the question, "please provide any general feedback in relation to the laboratory sessions not covered in the survey"

Comment category	Time allocation	Positive impressions	Learning based	Active learning	General structure
Key phrases	Too long; too short; rushed;	Good; fun; enjoyable; interesting	Helped understanding; learned most in lab; in-depth; deeper knowledge	Hands-on; apply knowledge; conducted own tests	Organized; uneven workload; not enough time for project
Number of comments	9	14	11	9	13

Figure 1: Word cloud consisting of key phrases summarized from student comments from the open-ended question, "please provide any general feedback in relation to the laboratory sessions not covered in the survey"



application of lecture content in the form of a laboratory. The significant difference in student responses, with a majority strongly agreeing, indicates a successful design and application of the flipped classroom in the laboratory setting was achieved. Here, students used their knowledge gained in lecture to design, conduct and analyze their own sensory tests during the laboratory.

One of the goals of the flipped classroom was to reserve in-classroom sessions for discussions, practice problems and activities (including group work). Out of class time is then reserved for reviewing content and lecture material. The researchers designed the lecture and laboratory activities so that the students' completed a majority of their group assignments during lecture and laboratory periods. The question addressed in Table 4, asking how much of the group project was completed during lecture and lab time, was, thus, an important metric to measure the success of the implemented flipped model. When significant differences in student responses, more than half (n=29, 58%) of the students indicated they completed more than 60% of the project within both lecture and lab. The remaining 40% of the project that students completed outside the lecture and lab most likely revolved around preparing PowerPoint presentations and lab reports. These were two assignments that the TAs for the course noticed students did not have much time to work on during laboratory sessions. While the instructor and TAs hoped that the students would have all of the group project work completed during lecture, the results presented in Table 4 illustrate an area for course improvement.

Creating additional time in the laboratory for group work is a challenge for the instructor and TAs, as the addition of one activity often includes the need to eliminate or shorten the time required on another task. Changes such as these require a careful examination of lectures and activities performed to determine what content is pertinent to the student's success. While sacrificing essential course content is not required in a flipped classroom (Lage et al., 2000), decisions reevaluating course content were made in the redesigning this course. For example, considerable time in lecture and lab was previously spent on learning how to determine the statistical probability of events occurring using z-scores. While this is an important statistical concept to grasp, it is most likely addressed during introductory statistics classes prerequisite to this course. It is also not used in the analysis of any collected data for student projects in the flipped laboratory. Because of these reasons, the decision was made to eliminate this lesson from the course. Class time was better spent on activities and discussions that furthered the progress of the group assignments. Other non-essential lecture topics were generally provided as supplemental texts available online. A thorough understanding of the course structure and pertinent content was necessary to correctly adjust topics in the course.

Student open-ended comments offered interesting perspectives related to the course that is otherwise difficult for the instructor and TAs to observe. As shown in Table 5, summarized in Table 6 and visually represented in Figure 1, student comments focused on time allocation of course activities, how the course contributed to their learning, the active learning components of the course and the overall structure of the course. Based on comments, it is clear that students have a great deal to share on the general structure and allocation of time for activities in the course. In this category, comments such as, "the labs were enjoyable and organized, however, some labs were far too rushed" or, "labs were good except when we were crammed on time" directly relate to the time allotted in each lab for activities. These comments on the "uneven workload" in laboratory sessions, also prominently displayed in Figure 1, alerts the course instructors that the allocation of time on certain activities needs to be adjusted. This is an unfavorable, but almost inevitable, consequence of a complete course overhaul. While the instructors designed activities to be completed in the time allotted, the actual time required to complete all activities by students was unknown. With experience, changes for subsequent years will be implemented to allow students' additional time on activities they struggled with and quicker movement through those they found easier to grasp. This should hopefully remedy the frequent "too long" and "too short" comments mentioned at higher frequency in Figure 1 and listed in Table 5. The challenge with these changes is the need to keep laboratory activities aligned with the flipped classroom lecture. Changes in the structure of activities in the laboratory will also require an evaluation of the lecture structure. Therefore, close collaboration with instructors on both ends of the course can make these type of adjustments work in the best interests of the students.

Since the flipped classroom is so different from other course structures, it is important for instructors to properly communicate the motivations behind its use to students (Hawks, 2014; Gilboy et al., 2015). When students understand the motivations of the flipped model, they will hopefully embrace and utilize their laboratory and in-class time effectively. While comments from students such as, “I got the most out of this class during my lab experiences, because they were a hands-on approach that explained things…” were a straightforward example of students seeing the benefits of the flipped classroom, other comments such as, “sometimes we did not get enough time to work on group projects” also illustrated a student who embraced the flipped model. The desire for additional time in lab is also shown in the Figure 1, with the key phrase “not enough project time” appearing as the largest phrase. With a changed mindset that laboratory and in-class time was a place to complete group work instead of a place to just absorb material, they wanted more time to complete their own work. With an understanding of the structure, students can embrace and rely on a structure where course time is designed to involve collaboration and completion of their group work (Hawks, 2014).

The flipped classroom and laboratory was designed to foster active engagement with the course material. Comments received from students reflected that laboratory activities did this effectively. Students commented on how they applied their knowledge in the classroom during hands-on activities conducted in class which lead to students commenting on how the laboratory helped in their understanding of the course material. The students had varying ways to express these comments, as shown by the wide variety of unique phrases visually represented in Figure 1. The researchers are unable to examine if student reported perceptions of increased understanding translates to better examination scores. While this may be a limitation to these research findings, other research has shown that students in active learning classrooms that self-reported having a better understanding of course material performed better on examinations (Everly, 2013).

Instructor Perceptions

Many of the positive outcomes seen in the laboratory regarding self-reported improved content understanding can be attributed to the active learning methods used. By providing students with a framework to design their own research instead of prescribed experiments, they were able to actively engage with the knowledge gained outside the laboratory to solve problems. Active learning techniques that promote student engagement have resulted in improved recall of information, student retention and academic achievement (Prince, 2004). The instructor and TAs of this course saw how active learning sparked interest and excitement, creating an environment where students created their own content instead of following a prescribed laboratory manual. It is believed that the use of group work, a cornerstone of this course, further aids in the students’ learning process. As discussed by Prince (2004), collaborative learning surrounding group work can improve academic achievement, self-esteem, student attitudes and content retention (Johnson et al., 1998; Springer et al., 1999).

Two major concerns were expressed by students regarding group work. The first was being assigned a particular food product category for the entire semester. While the instructor and TAs thought this would help students become “experts” and take ownership of their project, it instead made many groups dislike their product. Along the same line, students also expressed concerns with having to work with the same individuals the entire semester. While the millennial student prefers group work and the social interaction that comes with it (Roehl et al., 2013), they also embrace changes and challenges. Due to this feedback, a rotation of food products and group members for each section of the course is now in place and has worked quite well for subsequent years.

In order to have students more comfortable regarding the amount of group work in this course, a lesson regarding group work has been implemented. A university faculty member specializing in group dynamics and leadership now presents on the benefits, challenges and foundations of group collaboration with each group creating a group contract. These contracts consist of rules that all group members must abide by. Many students opted to include deadlines for when assignments should be shared with the group, guidelines for communications and the role that each group member plays. We have found this exercise to be very beneficial and it was specifically mentioned by students as a component of the course they now find helpful.

Developing the laboratory manual for a flipped classroom was a challenge. For many courses, pre-designed or commercially available laboratory manuals and exercises may be currently in use. Due to the extensive integration with the course material, such a manual was not available for this course. So, the manual had to be developed by the instructor and TAs. While this required a considerable amount of time from the instructional staff, it was a necessity for the course to function properly and a worthwhile investment of resources. The newly developed manual utilizes exercises that not only advance the development of the students’ own sensory test, but also draw upon topics covered in lecture. Laboratory sessions, instead of being seen as separate entities, have become extensions of the classroom. The flipped classroom and laboratory work as one team-drawing upon knowledge and experience gained separately to create an effective learning environment. It is, therefore, important a laboratory manual that corresponds with the lecture content is created when implementing the flipped classroom in a laboratory.

While resources are required to develop exercises, lab materials and revised lesson plans for instructional staff; utilizing public, departmental, campus and university resources can ease the process. Techniques such as bringing in staff from other university departments to give guest lectures, leveraging skills from students interested in course development and close collaboration with instructors and instructional staff can help ease the process of a major course overhaul. As a bonus, dedicating time and energy to the development of these resources can free up time later in the semester. Teaching assistants in this course remarked that before-class preparation for these newly designed labs often required less time. Since students were in charge of designing, setting up and executing their own research, the TAs were no longer required to spend a great deal of time performing these preparatory activities. Additionally, the time freed up during laboratory sessions allowed for increased interaction with students. This allowed TAs to directly interact with and form connections with students creating a more welcoming and inclusive learning environment.

It is important to note that instructors take the role of a "guide on the side" in the flipped laboratory to allow students to have extensive engagement with the course material (King, 1993). Only by staying in this role will students be able to construct their own solutions to the problems they are presented with. Providing answers to problems may be satisfying for students in the moment, but ultimately will not benefit them. When confronted with real-world problems such as the ones presented in this course (i.e. in a job, internship, or other classes) these future scientists will be the ones others look to for answers. When at these times in their careers, they will be required to make decisions, produce results and solve complicated problems without the direct input from an expert (King, 1993). Traditional laboratories where manuals and instructors provide all the answers will not prepare students for the future. It is for this reason why structuring the laboratory the way it was in this course will better serve students. While initial frustrations and "growing pains" may ensure when adopting the flipped classroom, for students and instructors, transparency and clarity in the classroom is essential to its success. Providing clear lesson plans with outlines of laboratory objectives, goals, activities and probing questions to the instructors can help make the transition to instructor facilitated teaching easier for the instructional staff working in the flipped classroom.

Summary

Active learning exercises in the flipped classroom allowed students to become directly involved with the learning process. Combined with a laboratory that reflected on lecture material and focused on a semester-long group project, an environment where students had the maximum potential to engage and interact with course material was created. A newly developed laboratory section of this course, where students explored the topics of the course to design, conduct and analyze their own experiments was far more engaging and useful for student understanding. While the development and implementation of a flipped classroom can be a challenge, the benefits seen by instructors and students shown here make a strong argument for the utilization of these teaching methods. Leveraging public, departmental, campus and university wide resources helped in the creation of this course structure. It is encouraged that others wishing to make changes such as these use the resources they have available at their institutions. While every course redevelopment may encounter some "growing pains", it is important as educators remain focused on creating the optimal learning environment for their students. Staying in touch with students' perceptions through the use of surveys and informal feedback at different points in the semester is an excellent way to ensure you are creating an effective learning environment for the students.

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