A Model Curriculum for Flipping an Allied Health Microbiology Course

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ABSTRACT
The flipped classroom model is increasingly popular in higher education, due to a number of potential advantages. Students gain the ability to customize their learning by interacting with classroom concepts on their own schedule. By moving some content out of the classroom, instructors gain the ability to free up time for more active-learning exercises and to concentrate on higher-order levels of learning. This article describes a comprehensive curriculum for flipping an allied health microbiology course, including tips for video lecture content and for active-learning modules that can be used in the classroom.

Key Words: flipped classroom; microbiology; allied health.

Introduction
In the flipped classroom model (FCM), “that which is traditionally done in class is now done at home and that which is traditionally done as homework is now completed in class” (Bergmann & Sams, 2012). It consists of two parts: interactive group-learning activities inside the classroom; and direct, computer-based individual instruction outside the classroom (Ash, 2012; Bishop & Verleger, 2013). It is an approach that has gained popularity in higher education in recent years as instructors have recognized its potential positive impact on students’ perception of learning (Bishop & Verleger, 2013; Chen et al., 2017) and learning outcomes (Chen et al., 2018; Hew & Lo, 2018; Rodriguez et al., 2019; Shi et al., 2019) (though there is disagreement; see Chen et al., 2017; Gillette et al., 2018). Most proponents value the FCM because it allows the transformation of the classroom from a passive, information-transfer, didactic environment to a hands-on, student-centered, active paradigm (O’Flaherty & Phillips, 2015). Many instructors choose to flip their classroom in order to incorporate active-learning exercises into their courses, which Jensen et al. (2015) argue is the most critical factor in the improved student learning outcomes that have been reported in studies of the flipped approach.

A critical component of the FCM is that students are presented with classroom content, typically through a video lecture, prior to arriving in class (Brame, 2013). Students find that these videos provide flexibility (Roach, 2014; Gilboy et al., 2015) and the ability to customize the pace of their learning (Nouri, 2016). In fact, the evidence suggests that video lectures can have a positive impact on student outcomes. Brown et al. (2016) note that students supplied with optional video lectures came to class much better prepared than when they had been given textbook readings. Students tend to watch the videos, even when they were not specifically assigned. And those who did watch the videos were more prepared when they came to class (De Grazia et al., 2012). Importantly, they felt that the videos facilitated their understanding of the material, especially when it was coupled with a quiz (Long et al., 2016).

Thus, a successful foray into the use of the FCM requires the creation or discovery of two key components: (1) “lectures” and/or other internet-based tools for students’ at-home use and (2) a roster of active-learning exercises for in-class use. Collecting these resources can be a daunting proposition (Lo & Hew, 2017). The prospect of generating a script for each lecture and recording it along with an accompanying PowerPoint (e.g., a screencast) or other visual material can be overwhelming for an instructor already busy with lesson planning, advising, research, committee service, and so on. In addition, while the flipped approach allows more flexibility in the classroom, it also means extensive planning to find or develop activities that will be completed in place of the lecture.

In addition to the practical considerations, there can be a considerable philosophical barrier to adopting the FCM. Most higher-education faculty have come out of a culture of lecture as the tried-and-true way to teach and learn. Especially in graduate school, the paradigm of the professor or advisor as the one who bestows knowledge upon students (the “sage on a stage”; King, 1993) is nearly ubiquitous. It should not be surprising, then, that the standard lecture is still the primary pedagogical strategy (Roehl et al., 2013), comprising more than two-thirds of observed classroom periods in a recent study (Lund et al., 2015). Having come
out of these environments, instructors’ tendency to default to this approach can be powerful. These closely held beliefs create resistance to change, a situation that can be exacerbated by environments in which technological resources are scarce, or where institutional policy (e.g., not providing time away from the classroom to work on a flipped curriculum) creates additional obstacles (Wang, 2017).

Those of us who have become “converts” to the FCM, who see it as a superior pedagogical model, should do our best to reduce or remove these barriers for our colleagues. While that may be difficult, given the philosophical opposition that a coworker may have, it is relatively simple when it comes to the practical components: we should share what we have found or made. Rather than forcing instructors who have decided to adopt the FCM to gather and/or create all the necessary materials themselves, those of us who have already made the switch should share the materials we have already collected. To that end, presented here is a curriculum, consisting principally of publicly available resources, that I have developed over a number of years teaching an allied health microbiology course at a community college. My hope is that it will provide, at minimum, a starting point for any microbiology faculty seeking to flip their classroom.

○ The Curriculum

The curriculum was deployed using the Blackboard learning management system that is used in my institution. The class, Microbiology and Infection Control, is primarily taken by allied health majors and consists of 10 topics (Table 1).

For each module, a folder was created on Blackboard that was made available automatically when that portion of the curriculum was reached. In each folder were four components: (1) the reading assignment from the course textbook, (2) instructor-generated lecture notes and PowerPoint presentation, (3) a series of video lectures, and (4) a quiz.

Most flipped-classroom adopters prefer to use screencasts that they have created. This presents a number of advantages, primarily that students see and hear someone who is familiar to them and that the instructor can control a number of aspects of the videos, including the length, depth, and breadth of the content. For faculty who have access to screencasting software and microphone and video equipment that can produce high-fidelity recordings, this approach is preferable.

Making personalized screencasts may not be possible in some situations, but there is a plethora of content providers that can be utilized for this purpose in an allied health microbiology course, including these:

- Armando Hasudungan (https://armandoh.org)
- Bozeman Science (http://www.bozemanscience.com)
- AK Lectures (http://www.aklectures.com)
- Crash Course (https://www.youtube.com/user/crashcourse)

All of these content providers are suitable for use in a flipped classroom. Their videos are generally no more than 15 minutes long, which research suggests is preferred by students (Zappe et al., 2009) and avoids the problem of increasing inattentiveness as lecture length increases (Hartley & Cameron, 1967; MacManaway, 1970; Johnstone & Percival, 1976; Bunce et al., 2010). They all present information clearly, concisely, and at the appropriate level. They each have their idiosyncrasies, which students may like or dislike. For example, the Crash Course narrator speaks very quickly, which can be problematic for English language learners. Armando Hasudungan uses wonderfully intricate illustrations that are completed as the lecture is conducted. The AK Lecture instructor resembles a traditional lecturer, standing in front of a whiteboard and proceeding through concepts as an instructor might do in his or her classroom. Finally, Bozeman Science offers somewhat typical lectures, accompanied by simple computer graphics and animations. For each module, I included videos from multiple sources. In doing so, I hoped to avoid creating an obstacle to learning due to stylistic incompatibility. By compiling a roster of videos from these sources for each topic, I was able to construct a complete “lecture” with all of the content that would normally be delivered in the classroom.

The fourth component in each folder was a link to a quiz over the material. Each quiz consisted of ~25 multiple-choice or true/false questions, primarily based on the “recall” and “understand” levels of Bloom’s taxonomy (Bloom, 1956). There was no time limit on the quiz, and students had three opportunities to attain their highest grade. The due date for the quiz was midnight of the day before the lecture over that material. The quiz was intended as a low-stakes mechanism (comprising a small percentage of the overall grade) to promote the completion of the “lecture,” a strategy supported by other findings (Patanwala et al., 2017).

Upon arriving in class, the first activity was a review of the quiz. This was, in essence, a “muddiest point” activity, as the quiz results quickly revealed the concepts that gave most students trouble, allowing me to quickly identify an item that would need more attention during that day’s activities. Typically, there were two to five questions that a significant portion (>75%) of the class struggled with. After reviewing the quiz, a short introductory lecture was typically delivered, introducing the topic and reviewing the difficult concepts identified by the quiz results.

Most of the classroom time was devoted to one or more active-learning exercises, intended to highlight one or more critical concepts within the module (Table 2). These exercises were mostly

Table 1. Lecture topics.

|   | Introduction & Main Themes of Microbiology |
|---|-------------------------------------------|
| 2 | Bacteria                                  |
| 3 | Eukarya                                   |
| 4 | Viruses                                   |
| 5 | Microbial Nutrition & Metabolism          |
| 6 | Microbial Genetics                        |
| 7 | Physical & Chemical Control of Microbes   |
| 8 | Principles of Chemotherapy                |
| 9 | Microbe-Human Interactions                |
|10 | Host Defenses                             |

Table 2. Learning exercises.

|   | Learning exercises                                      |
|---|--------------------------------------------------------|
| 1 | Lecture topics                                         |
| 2 | Video lectures                                         |
| 3 | Learning due to stylistic incompatibility              |
| 4 | A complete “lecture” with all of the content that would normally be delivered in the classroom |
| 5 | A superior pedagogical model                           |
| 6 | Should do our best to reduce or remove these barriers for our colleagues |
| 7 | To that end, presented here is a curriculum, consisting principally of publicly available resources, that I have developed over a number of years teaching an allied health microbiology course at a community college. My hope is that it will provide, at minimum, a starting point for any microbiology faculty seeking to flip their classroom. |
| 8 | The curriculum was deployed using the Blackboard learning management system that is used in my institution. The class, Microbiology and Infection Control, is primarily taken by allied health majors and consists of 10 topics (Table 1). For each module, a folder was created on Blackboard that was made available automatically when that portion of the curriculum was reached. In each folder were four components: (1) the reading assignment from the course textbook, (2) instructor-generated lecture notes and PowerPoint presentation, (3) a series of video lectures, and (4) a quiz. |
| 9 | Most flipped-classroom adopters prefer to use screencasts that they have created. This presents a number of advantages, primarily that students see and hear someone who is familiar to them and that the instructor can control a number of aspects of the videos, including the length, depth, and breadth of the content. For faculty who have access to screencasting software and microphone and video equipment that can produce high-fidelity recordings, this approach is preferable. |
|10 | Making personalized screencasts may not be possible in some situations, but there is a plethora of content providers that can be utilized for this purpose in an allied health microbiology course, including these: Armando Hasudungan (https://armandoh.org) Bozeman Science (http://www.bozemanscience.com) AK Lectures (http://www.aklectures.com) Crash Course (https://www.youtube.com/user/crashcourse) |
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|12 | The fourth component in each folder was a link to a quiz over the material. Each quiz consisted of ~25 multiple-choice or true/false questions, primarily based on the “recall” and “understand” levels of Bloom’s taxonomy (Bloom, 1956). There was no time limit on the quiz, and students had three opportunities to attain their highest grade. The due date for the quiz was midnight of the day before the lecture over that material. The quiz was intended as a low-stakes mechanism (comprising a small percentage of the overall grade) to promote the completion of the “lecture,” a strategy supported by other findings (Patanwala et al., 2017). |
|13 | Upon arriving in class, the first activity was a review of the quiz. This was, in essence, a “muddiest point” activity, as the quiz results quickly revealed the concepts that gave most students trouble, allowing me to quickly identify an item that would need more attention during that day’s activities. Typically, there were two to five questions that a significant portion (>75%) of the class struggled with. After reviewing the quiz, a short introductory lecture was typically delivered, introducing the topic and reviewing the difficult concepts identified by the quiz results. |
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|   | **Table 2. Student learning outcomes (SLOs) and descriptions of in-class activities.** |
|---|----------------------------------------------------------------------------------------------------------------------------------|
| 1 | **Spread of a Pathogen** |
| | **SLO:** Identify the types of epidemics; define epidemiology. |
| | From [http://asmscience.org/content/education/curriculum/curriculum.15](http://asmscience.org/content/education/curriculum/curriculum.15) |
| | In this activity, students model a propagated epidemic using GloGerm, a commercially available product that glows under UV light. Students engage in “real-world” epidemiology, attempting to identify the index patient by tracing the record of interactions. This activity is done during the first week of class because it also serves as a good “get-to-know-you” exercise. |
| 2 | **The Bacterial Cell Envelope & Antibiotic Activity** |
| | **SLO:** Describe the cell envelope for gram-negative and gram-positive bacteria. |
| | From [http://www.asmscience.org/content/education/curriculum/curriculum.2](http://www.asmscience.org/content/education/curriculum/curriculum.2) |
| | Students distinguish between gram-positive, gram-negative, and archaeal cell envelopes by identifying the components. They then identify and describe three structures that are found in all types. Finally, students apply knowledge of the difference between gram-negative and gram-positive types by analyzing an experiment with antibiotics, one targeting the phospholipid bilayer and one targeting the peptidoglycan cell wall. |
| 3 | **Sickle-Cell Disease & Malaria** |
| | **SLO:** Define selection pressure, allele frequency, heterozygote, and homozygote; describe the Mendelian genetics of sickle cell phenotypes; describe the relative susceptibility to malaria for each of the sickle genotypes. |
| | Modified from [http://faculty.georgetown.edu/sandefur/handsonmath/downloads/pdf/scel-s.pdf](http://faculty.georgetown.edu/sandefur/handsonmath/downloads/pdf/scel-s.pdf) |
| | Students model the phenomenon of malaria acting as a selective pressure on the sickle allele. Allele frequency is simulated by generating a population with different numbers of colored beans (white for Hs and black for Hh). Students pick two beads to generate a diploid individual. SS individuals “die” from sickle cell disease and a coin is flipped to determine whether “AA” individuals acquire a malaria infection (which kills them). After each generation, alleles are counted to determine whether gene frequency changes. Post-exercise discussion centers around selection pressure, gene frequency, and the question of what will happen to gene frequency if an effective vaccine for malaria is developed. |
| 4 | **Eukaryote, Prokaryote, or Virus?** |
| | **SLO:** Compare and contrast the three categories of microbes. |
| | **Instructor-generated.** This is a simple worksheet that has a number of microbial traits (e.g., “has a cell wall,” “can be a pathogen,” “is an obligate parasite”). Students must assign each trait to one or more of the three microbial types (prokaryote, eukaryote, virus) by placing a checkmark in the appropriate column. Students then rewrite the information on a three-category Venn diagram. |
| 5 | **Calculating Bacterial Growth** |
| | **SLO:** Calculate generation time and growth rate; calculate the number of bacteria in a population given starting conditions; describe the effect of temperature on growth rate and generation time. |
| | **Instructor-generated.** This worksheet emphasizes the exponential nature of bacterial growth. Students deal with a number of concepts, including calculating growth rate and generation time, finding a population size given the starting population and incubation time, and calculating the generation time, given the beginning and ending population sizes. |
| 6 | **Transcription & Translation** |
| | **SLO:** Describe transcription and translation and identify the necessary “ingredients” for each. |
| | **Instructor-generated.** Students are supplied with a short DNA sequence, containing a protein-coding region. After reviewing some basic concepts in genetics, students are asked to transcribe and translate the sequence. Finally, students exchange sheets with a neighbor, introduce a mutation into the sequence, and return it for the neighbor to identify. |
| 7 | **The lac operon** |
| | **SLO:** Describe the structure and regulatory control mechanisms of the lac operon. |
| | **Instructor-generated.** The structure of the lac operon and its function are modeled using foam repressor protein, allolactose, and cylinders (representing DNA segments). |

(continued)
Table 2. Continued

|   | Modeling the Spread of Antibiotic Resistance? |
|---|---------------------------------------------|
| SLO: | Describe the principles of horizontal transfer and natural selection and how they relate to the emergence of resistance in bacteria. |
| From | [https://www.pbs.org/wgbh/nova/teachers/activities/0303_04_nsn.html](https://www.pbs.org/wgbh/nova/teachers/activities/0303_04_nsn.html) |
|   | In this activity, students exchange paper “plasmids,” some of which contain antibiotic-resistance genes. Administration of an antibiotic shows how some variants are eliminated while resistant individuals survive and become more predominant in the population. |

|   | Understanding Griffith's Experiment |
|---|-----------------------------------|
| SLO: | Define horizontal transfer and describe the four mechanisms covered in class (transformation, transduction, conjugation, transposons). |
| Instructor-generated: | Students complete a step-wise analysis of Griffith’s transformation experiment. For each of the four experimental groups, students describe the experimental setup and outcome. This is followed by a series of genotype-phenotype questions. Finally, students review other forms of horizontal transfer. |

|   | Immunity & the Spread of Influenza within a Population |
|---|-------------------------------------|
| SLO: | Describe the types of epidemics; define herd immunity; identify risk factors for influenza. |
| From | [https://www.asmscience.org/content/education/curriculum/curriculum.14](https://www.asmscience.org/content/education/curriculum/curriculum.14) |
|   | This activity models the spread of influenza through two populations, one with a low vaccination rate and one with a high vaccination rate. |

|   | Microbial Control Concept Map |
|---|-------------------------------|
| SLO: | Compare and contrast the mechanisms of microbial control. |
| Instructor-generated: | This is a simple, fill-in-the-blank activity in which students use a supplied word bank to complete a chart comparing and contrasting the various methods of microbial control. |

|   | The Cells of the Immune System |
|---|-------------------------------|
| SLO: | Describe the role of various cell types in the immune response. |
| Instructor-generated: | This activity is based on an image from the textbook that shows the function of various immune cells, beginning with antigen processing and presenting the formation of the various classes of B- and T-lymphocytes. Students use a supplied word bank to identify all of the structures and processes occurring. |

|   | What is an ELISA? |
|---|------------------|
| SLO: | Describe the principles behind a direct and indirect ELISA. |
| Adapted from | [https://bit.ly/2x54OFA](https://bit.ly/2x54OFA) |
|   | Using laminated cards, students describe and place each of the steps of a direct and indirect ELISA in the proper order. |

gathered from publicly available sources, such as the American Society for Microbiology’s MicrobeLibrary (http://asmscience.org/VisualLibrary). Some were used as is, others I modified to be more suitable for the student population at my institution. Finally, I developed some simple activities myself.

For many instructors, the prospect of recording and editing lectures for an entire course is a hurdle to employing the FCM. While perhaps not suitable for every microbiology course, I have found the content providers and active-learning exercises described here to be appropriate for the upper-level sophomores that take my course at the community college where I teach. The curriculum presented here is intended to be a “starter kit” for instructors aiming to flip an allied health microbiology course. My hope is that this model curriculum might assist a new instructor — or a veteran instructor looking to incorporate a novel approach — in overcoming one of the obstacles to adopting the FCM.

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