The Dynamic Microbiology Classroom

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I. Background

The dynamic learning environment in BIOL 437 included the use of a variety of instructional technologies to increase student engagement and learning. These activities included online homework assignments through Pearson's Mastering Microbiology software (www.masteringmicrobiology.com), real-time course response and facilitated peer instruction using the online interactive software Learning Catalytics (www.learningcatalytics.com), concept mapping using MindMaple (www.mindmaple.com), and discussion of current research trends in microbiology through TED Talk discussions (www.ted.com). The effectiveness of the use of Mastering Microbiology and Learning Catalytics was assessed by the success rate of questions tagged by learning outcomes on unit exams. Student satisfaction and opinions were assessed for all four activities through a final course survey.

II. Project Description

A. Rationale

The activities incorporated into this course address several items highlighted by AAAS-NSF in their 2009 Vision and Change Report (www.visionandchange.org). This report was developed as part of the Vision and Change conference (Brewer and Smith, 2009) and includes several core competencies for higher education in the biological sciences. These competencies include 1) applying the process of science, 2) using quantitative reasoning 3) using modeling and simulation, 4) tapping into the interdisciplinary nature of science, 5) communicating and collaborating with other disciplines, and 6) understanding the relationship between science and society. Through conversations with 231 undergraduate students, 99 of which were biology majors, the Vision and Change report identified the desire of students to connect biology to other topics, both within STEM and more broadly. Students also noted that introductory courses are too broad, and that there needs to be less emphasis on memorization, more connections across the curriculum, and more relevance/context (Fry, 2009). The activities done in this project were directed at addressing these core competencies and student concerns.

B. Course Description

BIOL 437: General Microbiology is offered to biology majors who have completed BIOL 119 (Structure and Function) and CHM 116 (General Chemistry II). In fall 2014 this four-credit course had an enrollment of 29 students. The lecture meets for one hour three times a week and the lab component meets for three hours once a week. Most of the students are junior or senior level and need this course as a pre-requisite for advanced courses such as Principles of Virology, Medical Microbiology, Immunobiology, and Bacterial Diversity and Systematics. In addition, this course is a requirement for those applying to the Clinical Laboratory Sciences program at Parkview Hospital and for those pursuing the new Biology degree concentration in Microbiology and Immunology. The formal course description follows: "An examination of microbial diversity that emphasizes the interrelationship between bacteria and their environments. Special emphasis is given to metabolic diversity, control of microbial growth and interactions of pathogenic microorganisms with their hosts. The laboratory is designed to complement the lecture and emphasizes pure culture techniques, isolation and identification of unknown organisms, measurement and control of microbial growth and studies of human commensal organisms." While it is not possible to differentiate the learning acquired just in the lecture in a combined lecture and lab course, the focus of this project was on the lecture portion of the course. Quantitative analyses of learning outcome success rates were tabulated using lecture assignments and exams while surveys were strictly based on the lecture activities.

C. Implementation

The lecture portion of the course incorporated Mastering Microbiology (MM) homework assignments, Learning Catalytics (LC) real-time course response and facilitated-learning technology, concept mapping, and TED talk discussions. The first three activities were adapted for all 17 chapters while there were two TED Talk discussions for each of the four units. There were also four exams, one per unit with four to five chapters covered on each exam. MM and LC questions were tagged with learning outcomes for comparison to exam questions tagged with the same learning outcomes.

Learning Outcomes: The learning outcomes (LO) used in this study included six core concepts and several global outcomes. These outcomes were developed by the American Society for Microbiology (ASM) in 2014 (Stevens et al., 2014). In fact, part of the development was done at

the 2013 annual ASM Conference for Undergraduate Educators (ASMCUE) and I was one of the participants in this working group.

The six core concepts include 1) evolution, 2) cell structure and function, 3) metabolic pathways, 4) information flow and genetics, 5) microbial systems, and 6) impact of microorganisms. Within each of these categories there are four to five sub-outcomes or fundamental statements (Stevens et al., 2014). There are seven global outcomes. These are to 1) read and interpret graphs and data, 2) demonstrate an understanding of the principles of scientific inquiry, 3) demonstrate the ability to think critically and employ critical thinking skills, 4) demonstrate the ability to make connections between concepts across microbiology, 5) demonstrate and understanding of the impact of science on society, 6) apply the scientific method in lab experiences to interpret information and draw conclusions, and 7) demonstrate the quantitative skills needed to succeed in microbiology. Global outcome 6 was not used in the analysis since it is based on laboratory experiences.

MM, LC, and exam questions were developed and tagged with one or more LOs. Some questions in MM were already tagged by the publisher (Pearson Publishing) but most were uniquely tagged for this course. Most questions had more than one LO while several had three or more. Students were not shown the LOs assigned to each question. MM automatically calculated the percent success for each LO while the scores were manually tabulated for LC and exams.

Exams: There were four exams in this course, one per unit, each lasting 50 minutes. The final exam was not comprehensive but rather tested on the material from the fourth unit. Exams were worth 50 points and the first three exams had 40 MC, TF, or matching questions with 10 points worth of essay questions. The first three question types were all one point per question while essay questions varied in their credit. Due to time constraints, namely the concurrent grading of 29 written lab reports, the fourth exam did not have an essay component. Exams were written using the EZTest software by McGraw-Hill (www.eztestonline.com) which allowed the tagging of questions with LOs.

Mastering Microbiology: This program is part of the online software package included with the course textbook, Brock Biology of Microorganisms (Madigan, et al., 2014). Assignments were open for the entire unit, approximately four weeks, and students were instructed to complete them independently. Assignments were worth ten points, and consisted of a variety of multiple-

choice (MC), true-false (TF), matching, labeling, concept mapping, and ranking questions. Questions were scored as full or no credit for incorrectly answered MC or TF questions after one try while the other question types were scored as a 10% deduction per incorrect response up to six attempts. Average scores ranged from 7.8 to 10 and assignments took 18-38 minutes on average. For the most part, depending on the pace of lecture, assignments were due *before* the content was discussed in class.

Learning Catalytics: While LC is similar to other clicker course-response systems, it has many advanced features. One for the main requirements is that students use a wi-fi enabled device to participate and record responses. Most students used their smartphone, some used tablets, and a few used their laptops. Two students rented iPads that were granted to the Department of Biology through a separate proposal. There are 16 question formats in LC, in this course MC, many choice, matching, ranking, sketching, labeling, word cloud, short answer were used. Approximately three questions were delivered at the completion of the lecture presentation for each chapter. Questions were inspired from the course textbook test bank and were tagged in the LC software with LOs as appropriate. For the first half of the course questions were delivered, students had time to register their responses on their device, and the answers were shown and discussed as a class. In the second half of the course, about one question per chapter was followed-up with peer-based learning. For this, the question was asked and responses were recorded as described above. However, instead of discussing the result, the instructor shared the percent success and then used the LC software to pair students for peer-learning and to resubmit their agreed-upon response. When students logged into the course for each session they selected their seat on a virtual seat map. LC then pairs students with someone next to them in a way that matches students that got the response correct to another student that got it incorrect. Despite not knowing who was right or wrong, the percent success almost always went up following the peer-learning. Learning Catalytics grades were based on participation and not on performance.

Concept Maps: One of the major issues with STEM courses is that there is so much material and students tend to focus on memorization rather than application and context (Seymour and Hewitt, 1997). To help students see connections concept mapping was done to provide a graphical display of the organization of several concepts (Wandersee, 2002). This was done with the software program MindMaple which is compatible with Windows, Mac, and iOS devices. Concept maps were assigned for every chapter and for the first three units (13 chapters) a

complete word bank was provided. These word banks consisted of the central topic, a small list of level 2 subtopic terms (first branch), and several level 3 and 4 terms (subsequent branches). Maps were done for each chapter as individual assignments and due as a set on the exam day for each unit. An example was done in class for the first chapter. The maps for the first unit were thoroughly graded but due to the time demand, the remaining units were graded by focusing on one major branch per map. Maps were worth 10 points each unit and a half point was deducted per incorrect placement on the representative branch graded for units 2 and 3. Unit 1 maps were graded more subjectively. For unit 4 a limited word bank was provided for each of the four chapters, essentially lacking terms for levels 3+. Students were instructed to use the skills developed in earlier units to develop their own maps with a few restrictions; they had to cover the content in the respective chapter and contain at least 25 unique terms. For unit 4 all students received 10 points for completing the assignment.

TED Talks: TED stands for "Teaching, Education, and Design". TED talks are essentially lectures given by experts in the field about some topic of interest through global conferences. These talks are not formal lectures over traditional classroom subjects, but rather provide a focus on broader applications, which align with the speaker's area of expertise. Examples of TED talks related to microbiology include, "Meet you microbes" by Jonathan Eisen, "What's left to explore?" by Nathan Wolfe, "Good germs make healthy buildings" by Jessica Green, and "How bacteria talk" by Bonnie Bassler. There were two TED talks shown and discussed per unit on the day before each respective exam. Students worked in groups of three to four to review their assigned talk, develop a handout, and facilitate discussion of the talk in class. The handouts included a summary, its relevance to microbiology and society, and a brief biography of the speaker to better understand what it means to be a scientist. The assignment was worth 15 points and all students received full credit.

III. Results

A. Objective

The objective of this project was to identify engaging activities which resulted in an increase in student learning. Student learning was assessed by tracking exam success by LO and through a student survey. While it is impossible to truly differentiate the individual contributions each

resource had on learning, the results will be presented according to each resource in an effort to highlight the impact of each activity.

B. Learning Outcome Summary: Mastering Microbiology and Learning Catalytics

LOs were tagged in every MM and LC question. The total number of questions tagged for each core concept and sub-outcome were tallied per unit and overall. Exam questions were scored according to the percent correct and tagged as done for MM and LC for each unit and overall. The results are shown in Figures 1 and 2.

When the number of questions presented in MM or LC for any given outcome is compared against exam percent success scores, the hope is for a positive slope in a linear line of best fit. This would indicate that as the number of questions tagged for any given outcome increase, the better students would perform for that outcome one the exam. Essentially, the more the outcome is addressed, the better student performance. Figure 1 shows the results for MM using broad core concepts (top panel) and narrow sub-outcomes (bottom panel). In this analysis the slopes are slightly positive (0.02 and 0.10) suggesting a slightly overall positive effect on student learning for MM. However, the slopes were not found to be significantly different from zero, ultimately indicating that there was no measurable positive impact on learning. A similar result was found for using LC. Figure 2 shows that the slopes are positive (0.44 and 0.28) when grouped by core concepts or sub-outcomes. While this suggests that learning did improve through the use of LC, the slopes for LC were also not significantly different from 0 and a positive correlation could not be supported. One other interesting observation is that LC appeared to be more effected than MM for student learning based on this assessment, with positive slopes of 0.02 and 0.10 for MM and 0.44 and 0.28 for LC. Unfortunately, since each of these slopes were not significantly different from zero, the significance of the difference cannot be properly compared between those found for MM and LC. While it is disappointing that quantitative support for the positive impact of these technologies cannot be established, student opinion surveys provide evidence that MM and LC were key components to their ability to succeed in the course.

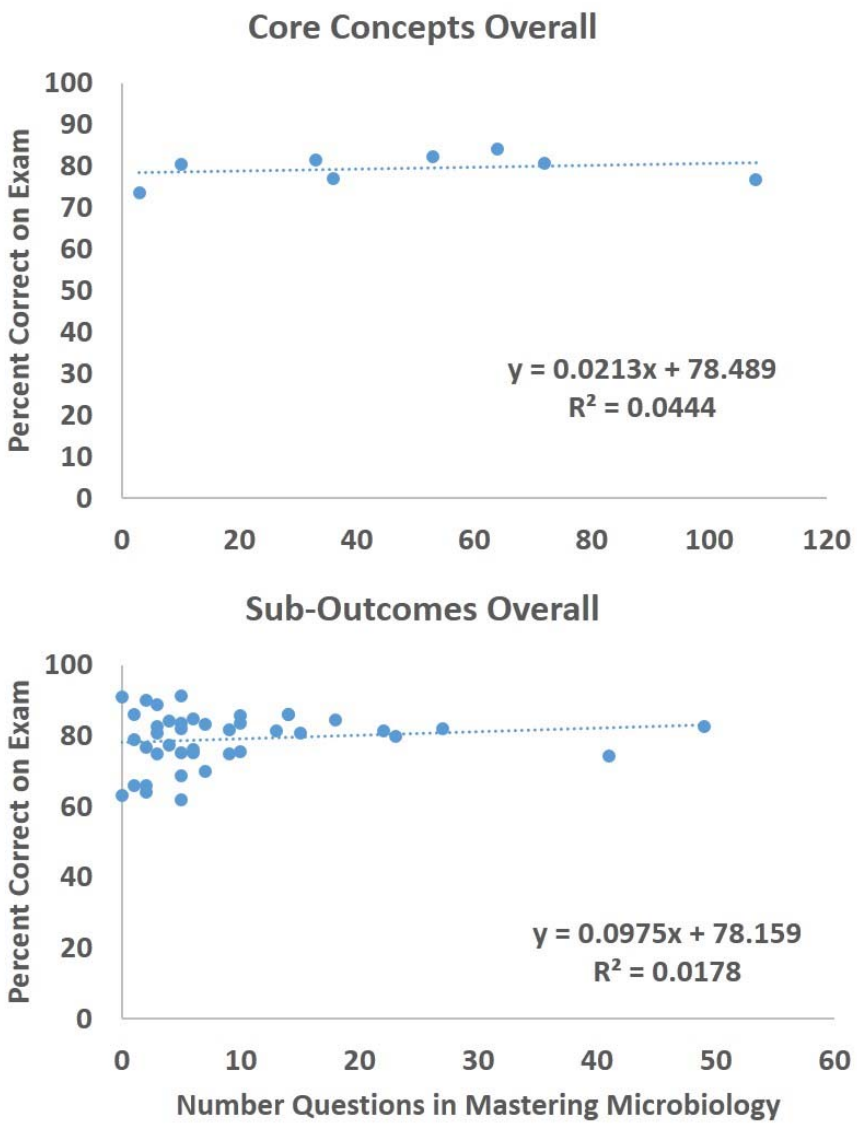

FIGURE 1: LEARNING OUTCOME RESULTS FOR MASTERING MICROBIOLOGY

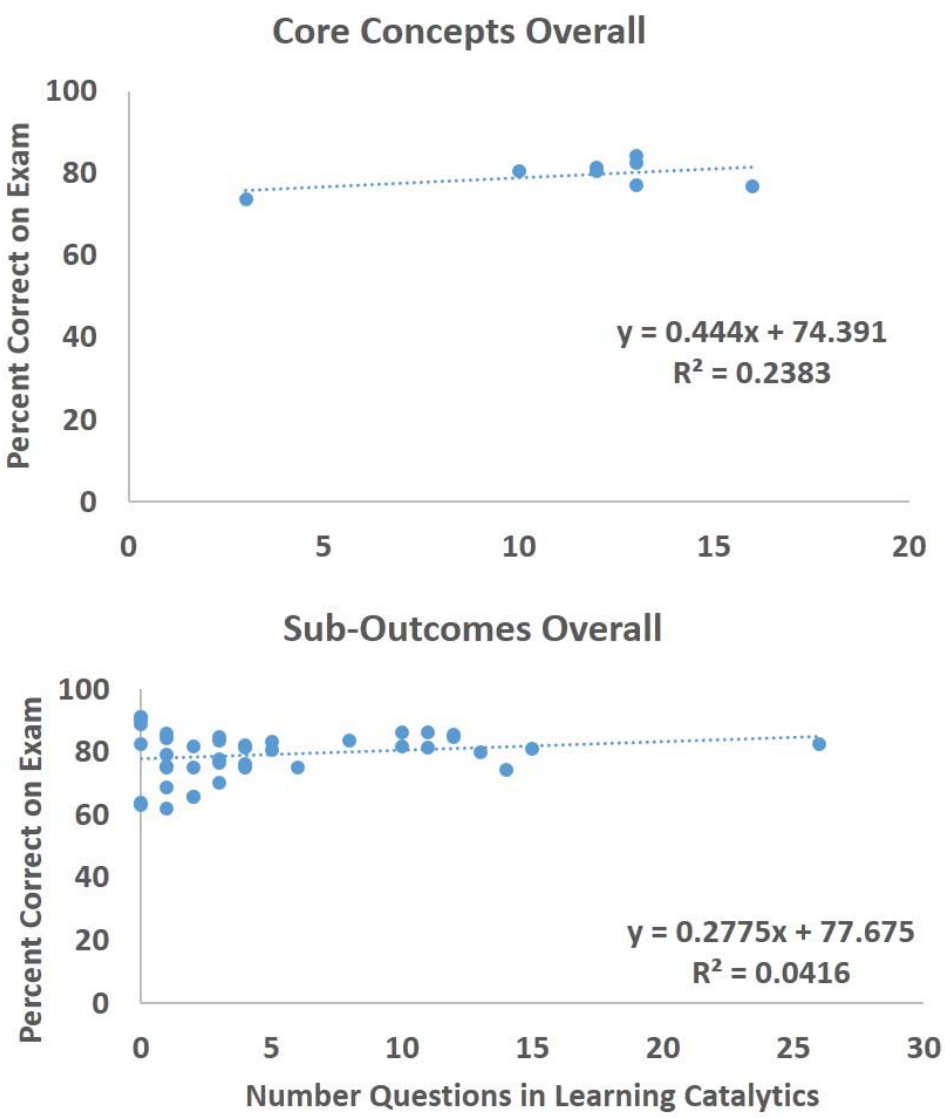

FIGURE 2: LEARNING OUTCOME RESULTS LEARNING CATALYTICS

Students were surveyed over their satisfaction and opinion of the activities. The response rate was 100% with 29 completed surveys in a course of 29 students. On a scale of 1: Strongly Agree to 5: Strongly Disagree, students noted that both MM and LC were key components to their success in the course and recommended their use in future BIOL 437 classes (Figure 3). Even though they found MM and LC important and recommended their use in the future, only about half of them actually used these resources to prepare for exams. Another observation is that most students favored the peer-facilitated learning activities in LC and enjoyed consulting

with their classmates. Among the comments submitted for MM, students generally had positive feedback. They noted that it was among the best online homework programs they had used, that the homework was challenging but very helpful, and that the exams paralleled with the homework assignments. One common criticism was that students felt it should not be scored so strongly since the content had not yet been covered in class. The comments for LC were very different than for LC. Aside from one comment out of 14, all of the students enjoyed LC. Some noted that they liked how it broke up the monotony of lecture, others thought it helped solidify concepts while even teaching them things they would have had trouble with otherwise, some even appreciated how it helped them know their classmates. A few students noted that LC was better than clickers they used in other classes, although one student disagreed. The main criticism was with the technical issues. Since the program required a Wi-Fi connection and access required two levels of programs accessed only through Blackboard they found it cumbersome to access. Furthermore, there were several technical problems experienced by everyone, including the instructor. These problems were exacerbated by the long workstation login issue plaguing many of the classrooms last semester. Despite these problems, LC was a positive experience for the students.

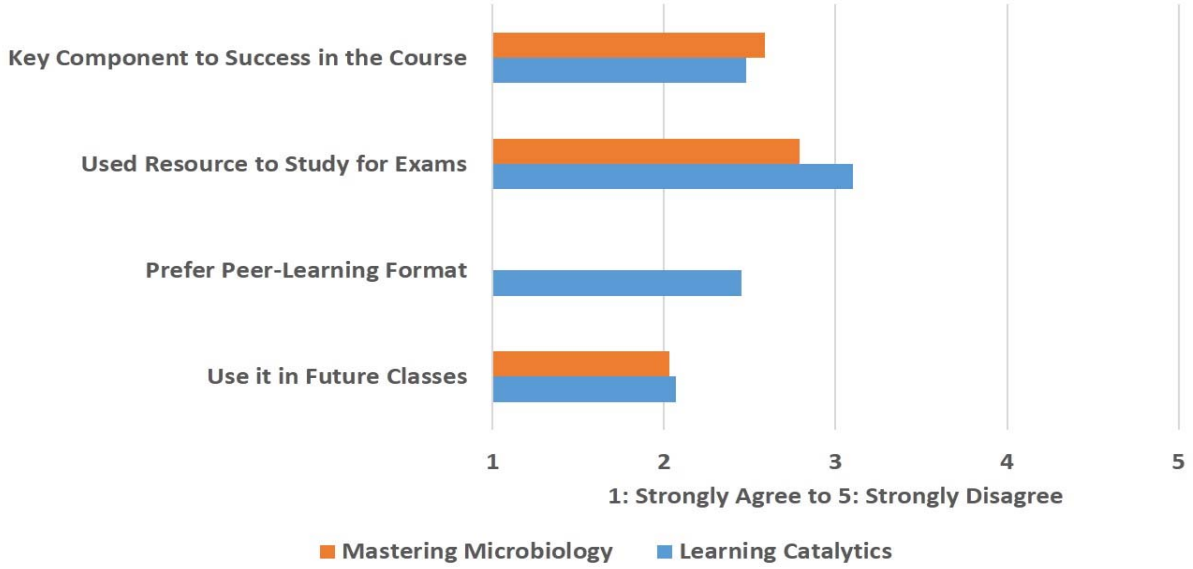

FIGURE 3: SURVEY RESULTS FOR MM AND LC

D. Concept Mapping

Concept maps were generated by every student for each of the 17 chapters covered in the class. For the first three units the word banks were provided but for the last unit students were only given the first two levels of words to start the mapping. For this unit, students had to construct their own maps based on their experience with mapping from the first three units. The maps from the first unit were graded in their entirety. While most students earned full credit, the maps did reveal some misunderstanding of the material for some students. This was helpful but due to the high time demand for minimal return a more streamlined grading method was developed. For units 2 and 3 maps were graded based on one major branch. It was expected that this branch would serve as the representative for how well the student understood the chapter. This method appeared to work well and drastically cut down on the time spent grading while still allowing for meaningful assessment. Since it was not possible to track LOs for mapping assignments, student surveys were used to gauge their effectiveness and usefulness to the students. Despite the time invested in completing the maps, they were a favorable activity for most students (Figure 4). For the most part students found them helpful and used them to study for exams and recommended using them in future BIOL 437 classes. It was also surprising to see that some of them even plan to use them in other courses.

There was not, however, a clear preference for making their own maps as in unit 4 or being provided with the full word bank. For this section there were 18 student comments and the opinions were most concentrated on the difference between mapping with a provided word bank (units 1-3) and mapping with the student's own words. A few students were strongly opposed to making their own maps, citing how they just added notes from the lecture slides in order and that the provided words were typically more helpful in knowing what the instructor found important in each chapter. Aside from those comments, most students praised the use of concept mapping and how much they learned by doing their own word banks. The noted that providing their own words made them read more carefully over the material, avoiding the puzzle of trying to guess where the instructor wanted each provided word placed, helped them synthesize and visualize the material, and how it reflected their own study methods. One student even said that the provided word bank maps were useless but completely changed their mind about mapping once they made their own word lists. One common suggestion was for the maps to be due before the exams and to receive feedback on them. Students thought this would make them an even better study tool.

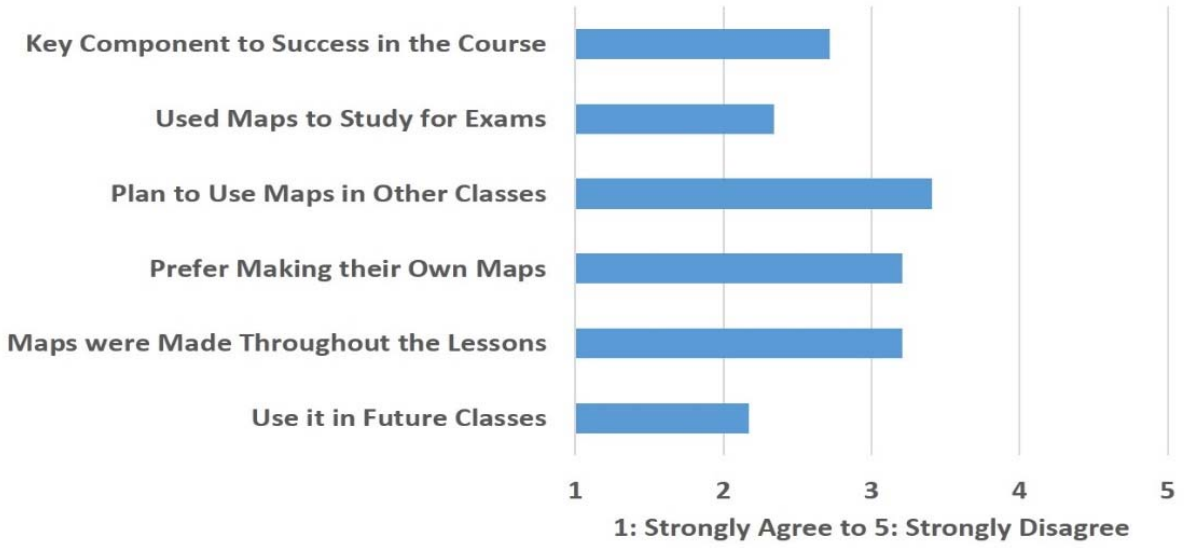

FIGURE 4: SURVEY RESULTS FOR CONCEPT MAPPING

E. TED Talk Discussions

TED Talk discuss assignments were done in groups of three to four and included a handout. Two talks were viewed in class on the session before each exam over material relevant to the exam content. Talks were chosen by the instructor and students chose which one they wanted to present. TED Talk material was not tested on the exams. Overall the student survey results were favorable and they seemed to enjoy the assignment. They seemed to help students better understand microbiology and most recommended using them in future classes. Among the 16 comments, however, the opinions were split. Some said that the TED Talk discussions should be used in every class to help students see relevance and that they thoroughly enjoyed them. Several others said they were useless, busywork, and that the session before an exam would be better spent reviewing or doing LC questions.

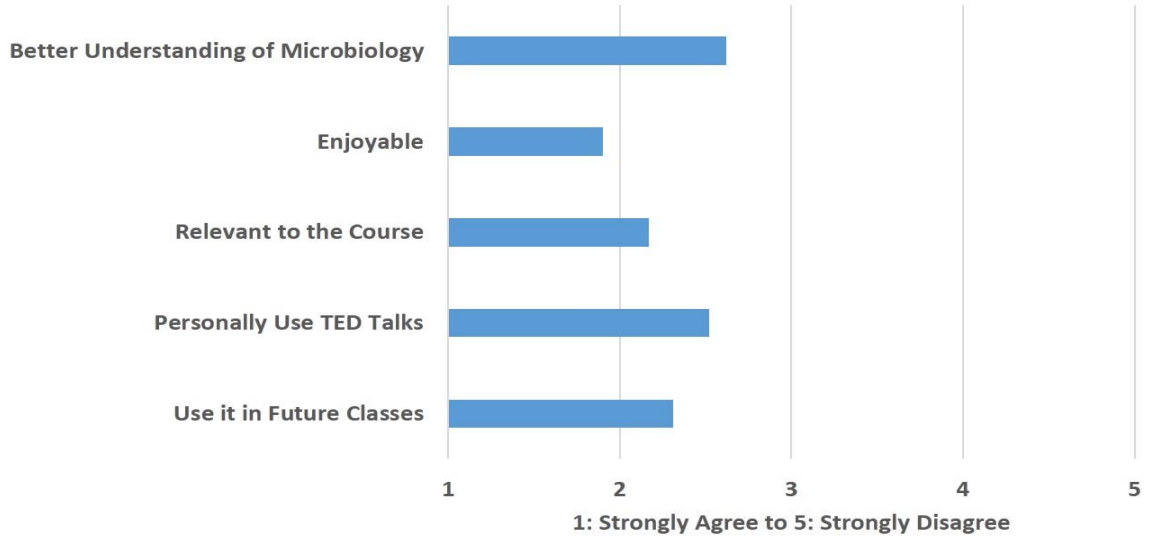

FIGURE 5: SURVEY RESULTS FOR TED TALK DISCUSSIONS

F. General Course Survey Responses

In addition to asking questions about specific resources, several survey questions addressed some general aspects of the course while others asked students to rank the resources according to different factors. Surveys were issued about a week before the final exam and students had until the exam to complete them. The class as a whole was given two extra-credit points if at least 27 responses (of the 29 students) were recorded.

Once concern was that the amount of resources would result in too high of a workload for the students and ultimately turn into busywork. When asked on a scale of 1: Far Too Much to 5: Far Too Little, the student response average was a 2.59 for the lecture portion of the course, affirming that the workload was reasonable. A similar response was recorded for the depth of material covered, difficulty of exams, and how challenging the course was to the student. These responses were assuring and suggested the course was at the right level for their background. The resources were also ranked according the usefulness and how much the student's enjoyed them (Figure 6). The most useful resource was MM while the least were the TED Talk discussions. Alternatively, the TED Talk discussions and LC were the most enjoyable while the textbook and maps were the least enjoyable. To study for exams, after lecture notes, there was a pretty even split with most used resource as MM (17%), concept maps (16%), and the textbook (15%) with LC used the least at 6% (Figure 7).

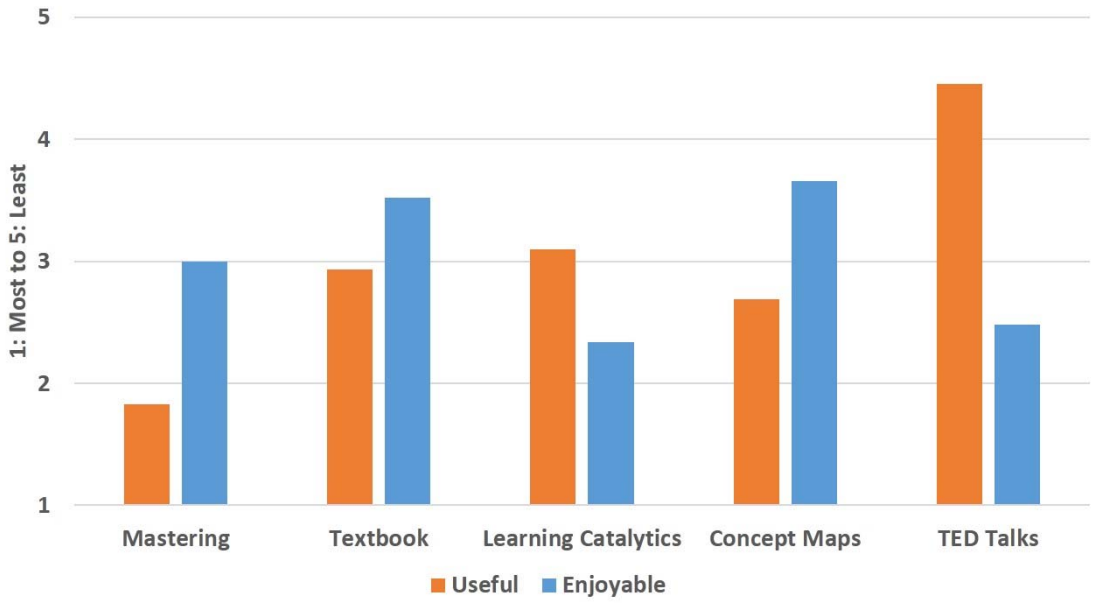

FIGURE 6: OPINIONS OF COURSE RESOURCES

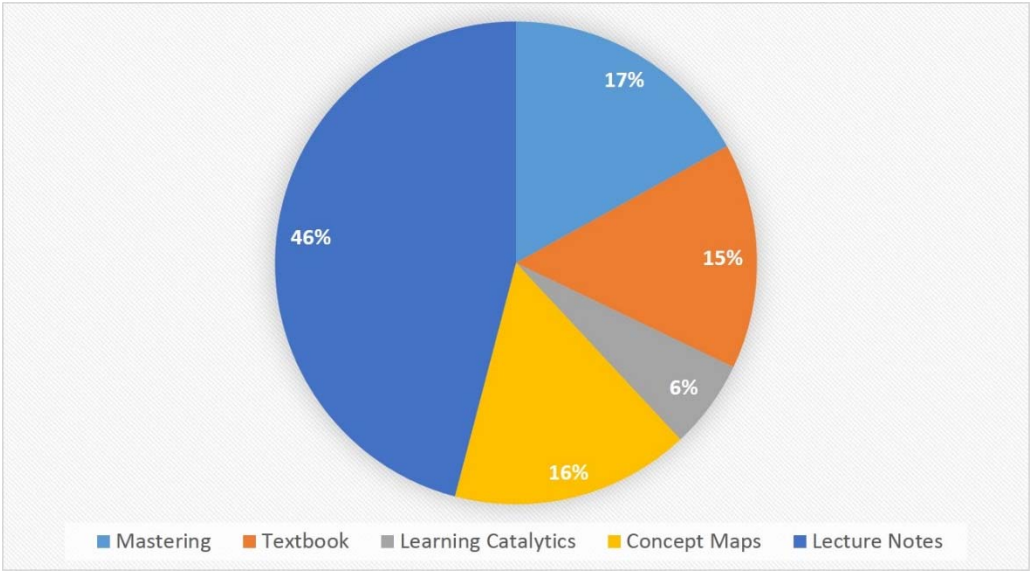

FIGURE 7: USE OF MATERIALS TO STUDY FOR EXAMS

IV. Conclusions and Future Directions

Overall this project was a positive experience for everyone. As the instructor, I was not only able to use a variety of new resources and ideas in my classroom, but I actually got to evaluate their effectiveness in a formal manner. Tracking LOs in MM, LC, and exams was very time-consuming and each activity took much longer to prepare than it would have otherwise. This was especially cumbersome since this was the first time I taught this course and I already had so

many other things to do to properly prepare it, including a complete redesign of the lab experience. Despite the time, I was able to successfully assign LOs to every single question on each assessment. One possible issue with assigning so many LOs was that my opinion wavered from day to day. Sometimes many LOs were assigned to a question while other times only a few seemed to fit. I found myself more conservative on some days and less on others, especially towards unit 4 where many of the questions had over three LOs assigned to them. I'm not sure this is really a problem but is something I noticed. It was disappointing that the overall positive correlation between the use of MM and LC and student learning did not have statistical support. The survey responses certainly supported the use of these resources and I plan to use them both again next fall with some changes based on student comments. I plan to decrease the weight of MM homework assignments on the overall course grade. Many students felt that since the material had not been discussed in class it was stressful and difficult to do well with so many ways to lose points. I will not make the MM assignments extra-credit or grade them on completion but I may reorganize the point structure in the future. Another suggestion was that LC would serve as a great study tool the session before an exam rather than TED Talk discussion. In the future I plan to do all LC at the end of the unit with more peer-instruction. This will not only serve as a tool for an in-class review session but also be more effective since most students will be better prepared to participate just before an exam.

Concept maps were well-received and the comments were mixed as to whether students wanted a provided word bank or to make their own, although the latter seemed to be more favorable. In the future I plan to provide a word bank for just the first unit and allow them to make their own for the subsequent units. I also plan to have the maps due earlier so that they can receive useful feedback for studying. To make the grading manageable, I may also integrate some form of peer-grading. While students enjoyed the TED Talks and the "break" from lecture they did not like that they took place just before an exam instead of a review session and that the assignment associated with them felt like busywork. In the future I will move the TED Talk discussion to the first session *after* exams 1 through 3. Instead of the handouts I may have a short quiz on the talks. This way they will still get exposure to the topics and feel as though the time was relevant to their success in the course.

The overall course survey responses were quite interesting with students citing that while the concept maps were among the least enjoyable activities, they were used just as much as MM

and the textbook for studying. Along the same lines, even though the students didn't really use TED Talks or LC directly in their studying, they found them the most enjoyable activities. These comments justify the continued use of all four resources for either their value to studying or for their contribution to the overall enjoyment of learning. The changes noted above are expected to improve student learning from the past fall. To test this, I plan to repeat the same type of analysis next fall with the changes noted above. Following analysis, I hope to not just see a positive correlation between these activities and student learning, but a quantitative one as well.

REFERENCES

Stevens, A., K. Hung, M-K. Liao, and S. Merkel (2014) General Microbiology Learning Outcome Examples. American Society for Microbiology, Washington, DC.

Brewer, C. A. and D. Smith (2009) Vision and change in undergraduate biology education: A call to action. American Association for the Advancement of Science, Washington, DC.

Briscoe, C. and S. U. LaMaster (1991) Meaningful learning in college biology through concept mapping. *American Biology Teacher*. 53(4):214-219.

Fry, C. (2009) Vision and change in undergraduate biology education: Preliminary reports of conversations. American Association for the Advancement of Science, Washington, DC.

Madigan, M. T., J. M. Martinko, K. S. Bender, D. H. Buckley, and D. A. Stahl. Brock Biology of Microorganisms. 14th Ed. Pearson Education, Inc.

Seymour, E. and N. M. Hewitt (1997) Talking about leaving: Why undergraduates leave the sciences. Westview Press. Boulder, CO.

Wandersee, J. (2002) Using concept mapping as a knowledge mapping tool. *In* Mapping biology knowledge. Fisher, K., J. Wandersee, and D. Moody (eds.) Springer. Dordrecht, Netherlands. pp. 127-142.

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