Spring 5-1-2018

Breaking Out From Tradition: Redesign of Large Physiology Lecture Increases Engagement, Inclusion, and Student Outcomes

Jordyn Dickey
University of Connecticut - Storrs, jordyn.dickey@uconn.edu

John Redden
University of Connecticut - Storrs, john.redden@uconn.edu

Kristen Kimball
University of Connecticut - Storrs, kristen.kimball@uconn.edu

Breaking Out From Tradition:
Redesign of Large Physiology Lecture Increases Engagement, Inclusion, and Student Outcomes

Jordyn William Dickey

Mounting evidence suggests that traditional lecturing is less effective, less engaging, and less inclusive than active learning. However, transitioning to active learning, particularly in a large science course, presents unique administrative and pedagogical challenges. Here, alongside professors Kimball and Redden, I present the results of the recent effort to redesign and restructure the large human anatomy and physiology course at the University of Connecticut to emphasize active learning and inclusive teaching. As an alternative to our traditional lecture, we subdivided hundreds of students into “break out” groups of no more than five students, which met concurrently during the scheduled lecture time. Grouped students were given interactive instructional modules designed with attention to scientific teaching techniques (active learning, inclusive teaching, assessment). Each group was also given an undergraduate facilitator, a peer who had excelled in the class before, to guide them through the activities. At the end of the semester, students that participated in the redesigned section of the course were compared against peers in another section of the class that was unchanged. Students in the redesigned course performed better on exam questions related to redesigned modules. Performance on exams was generally less “discriminating”, with less disparity between higher performing and lower performing students. The majority of students gave positive feedback on the redesigned classes, and reported making good or great learning gains. We offer evidence suggesting that this model is more inclusive, and better liked by students than traditional lecturing.

Acknowledgments

This work was supported by the large course redesign grant initiative at the University of Connecticut (to Professors Redden and Kimball), and a travel award from the Office of Undergraduate Research (to myself). The authors wish to thank Dr. Radmila Filipovic, Mr. Fred Murphy, Mr. Shanu George, and our stellar cohort of undergraduate facilitators. We also wish to recognize our anatomy and physiology students for their patience with our ongoing changes to the course format, and our colleagues in the Physiology and Neurobiology department for their valuable input on the project. I would like to extend a special thanks to Dr. Redden for serving not only as an incredible mentor and advisor, but as a wonderful friend as well. Lastly, I thank my Honors advisor Dr. Simon for her patience throughout this process.

TABLE OF CONTENTS

Breaking Out From Tradition: Redesign of Large Physiology Lecture Increases Engagement, Inclusion, and Student Outcomes

Jordyn W. Dickey, B.A., Kristen H. Kimball, M.S., M.E.M., John M. Redden, Ph.D.
Department of Physiology, University of Connecticut, Storrs, CT 06268

INTRODUCTION

The introductory Human Anatomy and Physiology course at the University of Connecticut is traditionally taught in a large lecture format, with over four hundred undergraduate students seated within an auditorium-style classroom. However, while this is the most common teaching modality in our peer universities across America, it may not be the most effective (1,9).

There are several problems inherent in the large lecture format, most of which stem from the passive environment fostered by both the size of the room and the volume of students. Undergraduates report feeling disengaged in class, both in the delivery of content and in their ability to pose questions to, or interact with, their peers and instructors. Spatially, the physical arrangement of many large lecture classrooms is problematic. Fixed seats and technology restrict instructors from achieving physical proximity to students that helps to keep them engaged. Of greater importance, it can also severely restrict students' ability to interact with each other during class. Further, lecture pedagogy is often not inclusive; it does not teach to students of all learning styles. While auditory or visual learners may succeed in lecture, kinesthetic learners, those who learn through doing, lack opportunities for engagement (2). Although the merit of tailoring pedagogy to match learning styles continues to be hotly debated, other measures of inclusivity, such as disparity in student ability, unequal levels of preparation, and life experience outside the classroom, are important and often overlooked considerations in content-heavy courses. To better address these problems, we constructed, implemented, and later assessed a structural overhaul of our Human Anatomy and Physiology course.

THEORY

In designing the new course, we endeavored to create an inclusive classroom, and transition away from passive learning and toward active learning. Using scientific teaching practices, we devised three key principles that would comprise the framework of the redesign, as described below.

Active Learning Theory emphasizes the importance of student-student and student-instructor interactions within the classroom, in the form of collaborative creation of content, the development of peer relationships, and the free exchange of ideas. While instructors are available for clarification, the responsibility for learning the material is placed more directly on the learner. Allowing students the freedom to learn for themselves facilitates the creation of novel frameworks with which to understand material. Such semantic networks have long been correlated with enhanced brain activation and improvements in content mastery and retention (3).

Inclusive Teaching Theory describes pedagogy in which instructors present material in a variety of formats (visual, auditory, kinesthetic) to accommodate students of all learning styles. Inclusive classrooms move beyond one-dimensional displays of course concepts.
For example, an inclusive classroom would discuss a topic, illustrate it through some visual media (e.g. a flow chart or picture), and then might ask students to draw, act out, or otherwise

engage with the topic through physical movement. In practice, kinesthetic learning benefits from smaller rooms or venues with movable seats.

Assessments are typically valued primarily for their ability to assess content mastery and, by extension, the level of success by instructors in educating students. However, assessments can also inform teaching practices, and provide opportunities for students to identify their own gaps in knowledge. We broaden the idea of assessments to include formative and summative types, as well as feedback on instructor style and lesson plans.

INSTRUCTIONAL DESIGN: OVERVIEW

The course redesign was centered around the reallocation of some traditional lecture time to hands-on instruction, in line with several studies demonstrating the benefits of supplementing traditional lecture with "interactive engagement" strategies (4,9).

Each redesigned lesson was comprised of asynchronous components, completed by students outside of class at their leisure, and synchronous parts, where groups met to work through activities (Figure 1).

160 students in section 30 of PNB 2265 were divided into 32 groups of 5, and each group was assigned an undergraduate facilitator who had taken the course before. This constituted a "break-out" group. Instead of attending lecture, students within these groups worked through a series of hands-on activities in smaller, less restrictive rooms on campus. While the specifics of each lesson changed depending on the topic, the format remained consistent. Individually, students prepared for the activity by viewing and completing a brief online module on their own time

(asynchronous). Once in their break-out groups (synchronous), students: created a concept map with which to organize the material; built on their knowledge by applying specific components to broad concepts (in our case, determining the effect of pharmaceuticals on a body system based on their proposed mechanisms); and observed real world-applications of course material by completing a case study.

Following the activity, students submitted feedback on their experiences, and assessed their own understanding via a quiz (asynchronous).

INSTRUCTIONAL DESIGN: FORMAT

Priming

Studies have shown the effectiveness of "flipped" lectures in large lecture pedagogy, wherein students learn the fundamentals on their own and refine this understanding with details provided in class (5). Before class, our students viewed and completed an online module germane to the topic at hand, including a video and quiz. The modules provided a brief overview of material that would be covered more in depth during the activities.

Organizing

There is a growing consensus that students learn best when given the opportunity to understand the "big picture" before being presented with specific details (6). Accordingly, at the beginning of each lesson, groups were tasked with organizing the relevant organs, cell types, and secretions into a concept map.

In the case of the digestive system, students connected secretions, cell types, and target tissues of the gastric pit. For example, students connected Parietal Cells to their secretion Hydrochloric acid, and then connected this to Pepsinogen, the proenzyme of the endopeptidase Pepsin, which is activated by low pH. For the renal system, students focused their efforts on connecting the different parts of the Renin-Angiotensin-Aldosterone-System (RAAS) as it pertained to secretion and reabsorption in the nephron.

Building

The regulation of body systems is one of the most rigorous areas of study for students, particularly because of the interconnectivity between different cellular structures. To refine their understanding, students were tasked with researching common pharmaceuticals and, based on their mechanism, determining both micro (receptor or cell) and macro (tissue or organ) level effects.

In our lesson on the digestive system, students were asked to research the H+/K+ ATPase (Proton Pump) inhibitor Pantoprazole. With clarification from the facilitators, students would come to understand that inhibiting the Proton Pump would decrease the amount of Hydrogen ions secreted into the stomach, which would decrease HCl formation, and result in a less acidic environment (increase in pH). In a stepwise manner, the group saw how the small cellular change of inhibiting a membrane protein resulted in the larger organ-level effect of increasing gastric pH.

Synthesizing

Undergraduates, many of whom are over 18 years old, are considered adults, and thus learn as adults do. A central tenet of adult learning is the integration of real-world examples, building in practical applications of course material. Information is believed to be more readily obtained, and stored, as its perceived relevance increases (7). Therefore, it is crucial to offer opportunities for students to see how concepts within the classroom may extend to their own lives. The question of "Why am I learning this?" is almost always an obstacle for students and professors alike. Given the high proportion of anatomy and physiology students with medical aspirations, clinical links are particularly salient.

Break-out groups applied their knowledge from the previous activities to work through a guided case study on peptic ulcers (digestive system) and blood pressure regulation (renal system). The case study, led by the undergraduate facilitator, probed the group's understanding of key concepts by relating them to specific scientific methods and discoveries.

Reinforcing

Retrieval, the act of remembering or gathering information from memory storage, is associated with enhanced learning and cognition (10). Educators looking to increase their students' long-term retention of material should employ several strategies that require a form of recall.

On their own time after the break-out activities, students were asked to complete a quiz on what they had learned with their group. The quiz accomplished three primary goals. Firstly, the results allowed us to gauge the efficacy of our activities in educating students. Secondly, the quiz enabled students to retrieve, and thus reinforce, the key concepts that they had learned. Lastly, in completing the quiz, the students were given insight into their own level of content mastery based on how difficult they thought the questions were.

RESULTS

The purpose of this study was to identify the effect of course restructuring, moving away from large, passive lectures and toward active learning. To this end, we solicited student perceptions via open-ended feedback and through the Student Assessment of Learning Gains (SALG) instrument.

Solicited student feedback

Students in the redesigned class were asked to submit open-ended feedback regarding their experiences. These responses, while varied in length and content, were largely supportive of the course redesign **(**Figure 2). In particular, students felt the small group format facilitated an open and inclusive discussion, with peers and the undergraduate facilitator as allies in the activities. Further, students felt the physical act of creating helped them visualize and retain information. One of the key focuses of the redesign was to teach to all learning styles, including kinesthetic learners. Given the number of students reflecting positively on the interactive nature of the activities, we believe that our lesson was inclusive and effective for students of all learning styles.

Student Assessment of Learning Gains

To examine how the students perceived the activity, we utilized the Student Assessment of Learning Gains (SALG) instrument. This instrument is well documented as a reliable tool to gauge student-perceived academic changes (8). With SALG, we can probe student beliefs about any number of topics, including effectiveness of the small group format or grasp of specific topics in anatomy or physiology. Research on SALG indicates that students may not be the most reliable arbitrators of their own learning; they may overestimate the breadth of their learning, or underestimate just how much they have learned. However, students are good at assessing their *change* in understanding. In other words, while one may not know exactly how much they have learned, they know that they have, or have not, learned something. The gradations of learning gains (Great, Good, Moderate, Fair, None) are far less important than the amount of students who indicated at least a moderate level of learning gains.

One could describe success as a high proportion of students indicating Great, Good, or Moderate learning gains. Again, while the definitions of "great", "good", and "moderate" are arbitrarily defined, students who recognized such gains can effectively gauge the change in their level of understanding.

Students in the redesigned section (Section 30) were asked to self-report their learning gains on different concepts in both the renal and digestive systems on a scale of Great, Good, Moderate, Fair, or Poor. When asked to assess their learning gains on key physiology concepts addressed in the breakout activities, such as the regulation of the proton pump in the stomach, 94% of students indicated Great, Good, or Moderate learning gains (Figure 3). 97% of students indicated Great, Good, or Moderate learning gains about the regulation of Antidiuretic Hormone (Figure 4).

We acknowledge here a missed opportunity to ask these same questions of the control section, section 1, as comparisons were a key part of our assessment. Subsequent iterations of the course redesign have done this, however, and preliminary evidence suggests that more students in the redesign report Great, Good, or Moderate learning gains when compared to those exposed to traditional lecture.

Exam performance

In our inquiry, it was also useful to establish quantitative methods to probe the success of the course redesign. If the break out groups were successful, we would expect an increase in different parameters regarding exams, such as test scores.

Students in the redesigned portion of the class (Section 30) scored 2% higher on matched exam questions when compared to the other section (Section 1) who received traditional lecture pedagogy by the same instructors (Figure 5). In other words, when we compare exam scores for material covered explicitly in both the breakout activities and lecture, the breakout groups fare better. This discrepancy is constant in all question types, of varying easiness. In fact, the breakout section answered ~70% of questions more correctly than their peer section (Figure 6).

In our investigation, we were also interested in score discrimination, a statistical test used to assess how overall exam performance affected the likelihood that students would answer any particular question correctly. In practice, this tool examines how lower-performing students perform against their higher-performing peers. We can extend this definition to describe the inclusiveness of teaching. A lower discrimination would indicate that a pedagogy was effective at reaching students of all learning styles, not just those well-suited to traditional lecturing. Therefore, if our redesigned section had lower discrimination, we could infer that the activities accommodated those who learn by seeing (visual), hearing (auditory), and doing (kinesthetic).

Comparison of discrimination values between the redesign group and the control group suggests more inclusive teaching in the course redesign. There was a 4% decrease in discrimination for those who underwent the alternative lessons.

DISCUSSION

Despite the scientific consensus that alternative pedagogies improve student performance, departing from the traditional lecture format is often met with resistance from both professors and students alike. Instructors express concern over the practicality of interactive lessons, fearing less direct instructional time will translate into less material covered and a decrease in test scores or content mastery. Students may be apprehensive about working within a group, preferring instead to sit and "absorb" knowledge from the instructor.

We have demonstrated that students overwhelmingly approve of active-learning activities. We can also suggest that student performance and educational inclusion increase in the absence of large lectures. Importantly, students in the redesigned section did not perform worse than those in the traditional lecture; the course redesign was at least as successful as traditional lecture.

The results of our study add to a substantial body of research on the efficacy of active-learning and inclusive-teaching strategies in undergraduate education. We hope to incentivize the transition away from large-lecture pedagogy, and assuage any associated concerns. We offer educators and students alike a framework with which to develop new lesson plans that are more active and inclusive than large-lecture pedagogy.

ACKNOWLEDGMENTS

This work was supported by the large course redesign grant initiative at the University of Connecticut (to JMR/KHK), and a travel award from the Office of Undergraduate Research (to JWD). The authors wish to thank Dr. Radmila Filipovic, Mr. Fred Murphy, Mr. Shanu George, and our stellar cohort of undergraduate facilitators. We also wish to recognize our anatomy and physiology students for their patience with our ongoing changes to the course format, and our colleagues in the Physiology and Neurobiology department for their valuable input on the project.

REFERENCES

1. Lowe, W. (2011). Is the Sun Setting on Lecture-based Education? *International Journal of Therapeutic Massage & Bodywork*, *4*(4), 7–9.

2. Kolb, A., & Kolb, D. (2005). Learning Styles and Learning Spaces: Enhancing Experiential Learning in Higher Education. *Academy of Management Learning & Education*, *4*(2), 193-212. http://www.jstor.org/stable/40214287

3. Raposo, A., Mendes, M., & Marques, F. J. (2011, August 27). The hierarchical organization of semantic memory: Executive function in the processing of superordinate concepts. https://www.sciencedirect.com/science/article/pii/S105381191100989X?via=ihub

4. Knight, J. K., & Wood, W. B. (2005). Teaching More by Lecturing Less. *Cell Biology Education*, *4*(4), 298–310. http://doi.org/10.1187/05-06-0082

5. Tune, J. D., Sturek, M., & Basile, D. P. (2013, December). Flipped classroom model improves graduate student performance in cardiovascular, respiratory, and renal physiology. https://www.physiology.org/doi/10.1152/advan.00091.2013

6. Carr-Lopez, S. M., Galal, S. M., Vyas, D., Patel, R. A., & Gnesa, E. H. (2014). The Utility of Concept Maps to Facilitate Higher-Level Learning in a Large Classroom Setting. *American Journal of Pharmaceutical Education*, *78*(9), 170. http://doi.org/10.5688/ajpe789170

7. Palis, A. G., & Quiros, P. A. (2014). Adult Learning Principles and Presentation Pearls. *Middle East African Journal of Ophthalmology*, *21*(2), 114–122. http://doi.org/10.4103/0974-9233.129748

8. William, A. E., Aguilar-Roca, N. M., Tsai, M., Wong, M., Beaupré, M. M., & O'Dowd, D. K. (2011). Assessment of Learning Gains Associated with Independent Exam Analysis in Introductory Biology. *CBE Life Sciences Education*, *10*(4), 346–356. http://doi.org/10.1187/cbe.11-03-0025

9. National Research Council (US) Committee on Education on Dual Use Issues in the Life Sciences. Challenges and Opportunities for Education About Dual Use Issues in the Life Sciences. Washington (DC): National Academies Press (US); 2010. 2, A Primer on the Science of Learning. https://www.ncbi.nlm.nih.gov/books/NBK209830/

10. Karpicke, J. D., Blunt, J. R., & Smith, M. A. (2016). Retrieval-Based Learning: Positive Effects of Retrieval Practice in Elementary School Children. *Frontiers in Psychology*, *7*, 350. http://doi.org/10.3389/fpsyg.2016.00350

FIGURES

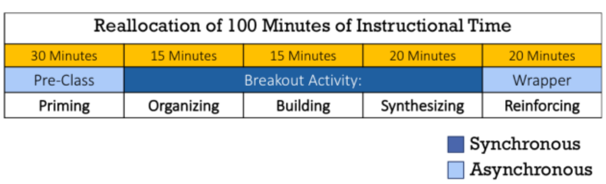

Figure 1. Reallocation of 100 minutes of Instructional Time between synchronous and asynchronous activities. Synchronous activities occurred within the classroom sequentially; asynchronous activities took place outside of the classroom before and after the synchronous activities.

Representative Student Feedback: Positive

"The small group activities were by far the most helpful thing we have done in class. It was much more hands-on and forced you to think and get up there. It was nice because even if you were wrong about something, it wasn't painfully embarrassing and the TA would explain why it is wrong."

"Drawing the transporters in the nephron was extremely helpful in understanding their function. The hypersensitive drugs allowed me to think more about where each of the processes were occurring in the nephron, which was very helpful. I liked being in a small group and being able to talk through and problem solve with others; being in a small group kept my focus and allowed me to actually reflect on what I know because my input was essential."

Representative Student Feedback: Negative

"I didn't attend either activities because I felt uncomfortable working in small groups with people I've never even met. I think that if you are going to make activities a thing, you should most definitely do it all year, rather than just twice. These activities felt kind of awkward and forced in their timings, so make sure that yall are ready for these activities, and make sure that you do them throughout the year, not just twice. This could allow people to get comfortable with their groups.

"I went to the beginning of one activity and I felt overwhelmed and left right away."

Figure 2. Select student feedback reflecting the most common positive and negative responses. Students remarked favorably on the hands-on nature of the activities, particularly about drawing anatomical structures. Some students felt the activity was overwhelming.

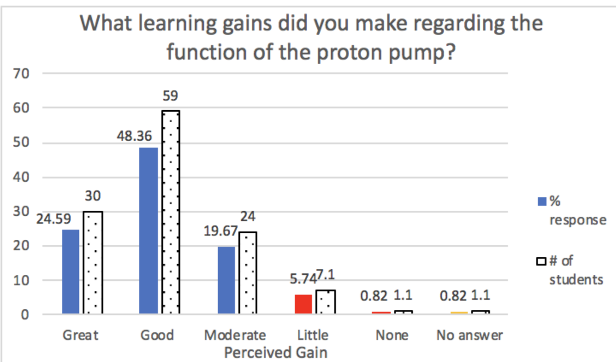

Figure 3. Student-perceived learning gains regarding the function of the H+/K+ ATPase (Proton Pump). Approximately 94% of students who responded to the survey had Moderate learning gains or higher.

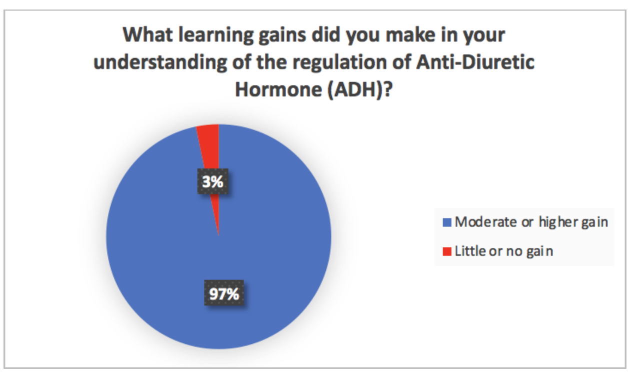

Figure 4. Student-perceived learning gains regarding the regulation of Antidiuretic Hormone (ADH). 97% of respondents had at least Moderate learning gains or higher.

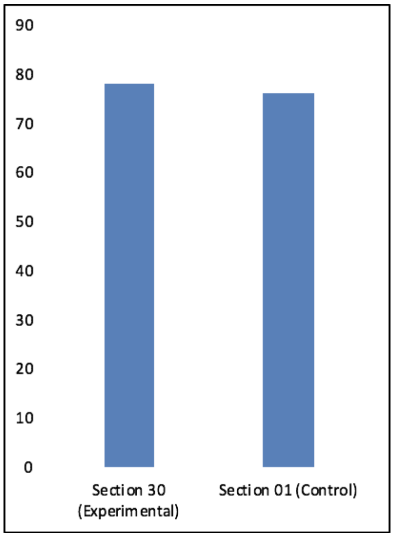

Figure 5. Students in the break-out groups (Section 30) scored 2% higher on matched exam questions when compared to those exposed to traditional lecture (Section 01).

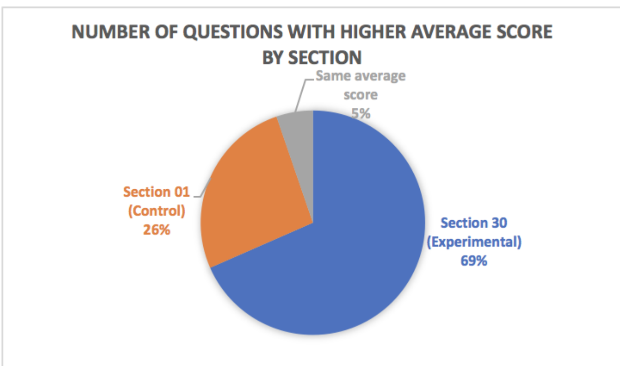

Figure 6. Students in the break-out groups (Section 30) had higher average scores on 69% of exam questions when compared to those exposed to traditional lecture (Section 01).

Understanding Gastric Acid Secretion: An Active Learning Approach

Jordyn W. Dickey[1], Kristen H. Kimball[1], John M. Redden[1]†

Affiliations:
[1]Department of Physiology and Neurobiology, University of Connecticut, Storrs, CT, USA.
†To whom correspondence should be addressed

Type of Manuscript: *CourseSource* Lesson Manuscript

Funding and Conflict of Interest: This work was supported by an internal grant from the University of Connecticut Center for Excellence in Teaching and Learning (CETL).

ABSTRACT

The human digestive system is a complex network of different cells and organs regulated by secretions, pH, and the microbiome. Given the volume of information covered and the dense physiology involved, both the teaching and learning of this system are challenging, particularly in a large lecture (400+) environment. In our Human Anatomy and Physiology course at the University of Connecticut, we developed a new approach to teaching the histology and regulation of gastric secretion using active learning activities moderated by an undergraduate facilitator. The lesson included a guided case study on peptic ulcer formation, a student-created diagram on the molecular mechanism of acid secretion, and a concept map linking the cells with their secretions and pharmacological regulators. Integrating these active-learning strategies created a more engaging classroom, providing an opportunity for students to reflect on broader concepts and practice critical thinking and problem solving skills. With this lesson plan, we offer educators a new approach to teaching the regulation of the digestive system with an emphasis on application of knowledge and the interconnectivity of course material.

Learning Goal(s)

- Understand the organization and function of the gastric pit
- Understand the molecular machinery responsible for acid secretion in the stomach, and how it is regulated by hormones, pharmaceuticals, and the nervous system
- Understand the cause of peptic ulcers

Learning Objective(s)

- Define the specializations of the apical and basolateral membranes of the parietal cell
- Explain how the proton pump is regulated by gastrin, histamine, somatostatin, and acetylcholine
- Predict the effects of pharmaceuticals that are active in the stomach
- Explain the role of *H. Pylori* in the development of peptic ulcers

BACKGROUND

At the University of Connecticut, Human Anatomy and Physiology is a two-semester integrated course for pre-health students comprised of both lecture and laboratory instruction. The lecture portion of the course, which meets three times a week for 50 minutes, is supplemented by an hour-long prelab module followed by a two-hour face-to-face laboratory. We introduce the digestive system about midway through the semester, after completing units on the cardiovascular, respiratory, and immune systems. As with the preceding systems, the digestive system is taught hierarchically, with an overview of gross anatomy (e.g. organs and tissue layers), histology, and major functions coming before more complex concepts such as cellular secretion, chemical digestion, and the regulation of these systems. The unit ends with the integrated meal response. The rationale for this approach is to have students develop a "big picture" framework with which to organize the regional specializations present in specific cells and tissues. This allows us to better place the individual components in the context of the entire system.cAs is the case with other complex physiological topics, understanding each component by itself does not necessarily result in understanding the system. However, this is not something that is easily impressed upon students who often struggle to transition from lower order to higher order learning. Moreover, misunderstandings about molecular physiology may occur because of a student's inability to relate the material to everyday life, as identified by the National Research Council (US) Committee on Education in their report *Challenges and Opportunities for Education About Dual Use Issues in the Life Sciences* (1).

To compound this problem, we have found that traditional lecturing on this topic does not sufficiently capture student attention, which not only results in learning gaps for students, but also contributes to wasted classroom time as the information often needs to be reviewed and repeated in subsequent classes. In accordance with the goals of the 2009 AAAS Vision and

Change in Undergraduate Biology Education summit, which stressed the importance of "outcome-oriented, active biology learning focused on deep conceptual understanding" (*as cited in* National Academies Press, 2010), we are making ongoing attempts to address these problems, and add relevance to the course content, by including real-life applications and hands-on teaching methods whenever possible. When given appropriate historical context and taught in an interactive way, challenging concepts can be made more accessible. Unfortunately, limited resources and instructional time often limit the ability to fully integrate these elements into undergraduate courses.

One example of the disconnect between knowing a fact and understanding a concept occurs in learning about acid secretion in the gastric pit, a complex process involving interplay between hormones, the nervous system, and secretory epithelia. However, understanding systems-level physiology is an expressed goal of many courses, and this complexity in the digestive system offers an excellent opportunity to make progress toward achieving it. We attempt to resolve this discrepancy by building in real-world connections, such as pharmacological agents, which bolster student interest and understanding of course material. Further, we analyze, stepwise, scientific discoveries and what their consequences are. Cooperative or group activities and dialogues are also valuable assets we employ to promote a greater understanding of multistep processes.

OVERVIEW

This lesson is comprised of three main parts: a concept map, a guided drawing of the gastric pit and parietal cell, and an interactive case study exploring the history and pathology of gastric ulcers.

Low order prerequisite information was introduced in previous lectures and a pre-class video. Students were also responsible for completing a pre-class assignment to demonstrate mastery, or (*see* Supporting Material S7: GI Pre-Class Assignment). terms introduced during previous lectures and online pre-class assignments (*see* Supporting Material S4: GI Concept Map Instructions).

In class, students were placed into groups and tasked with identifying relationships between accessory organs, secretions, and hormones in the digestive system using a concept mapping approach. For example, a group might connect Parietal cells with HCl, knowing that HCl is the secretion associated with this cell type. HCl might then be connected to Pepsinogen, a proenzyme secreted by the Chief cells, because the acid catalyzes the conversion of this precursor into its active form, Pepsin.

During the next part of the activity, students were instructed to place ion channels, transporters, and pharmaceuticals on a template of the gastric pit (*see* Supporting Material S2: Blank Gastric Secretion Template) that aligned with their pre-class assignment. Lastly, to address concerns about relevance to daily life and provide an exciting context for the information, we discussed an area of the gastrointestinal system via a historical lens: uncovering the pathology of peptic ulcers. Through an interactive case study, we investigated competing theories of *H. Pylori* infection and excess acid, as the causative agent of most gastric ulcers by having students design experiments and interpret results from historical studies (*see* Supporting Material S5: GI Case Study Presentation). Importantly, our investigation illustrated how the scientific consensus evolved over time to better reflect the evidence, a key hallmark of the scientific method that is often overlooked due to time constraints and the focus on research findings vs. research methods in applied courses like A&P.

In our execution of this activity, we used previous students from the course as "facilitators" for each group in order to maximize the instructor resources available to each group. The students in this group were prepared exactly the same as the students who participated in the activity, except they completed the activity two weeks ahead of time. Having been through the activity once themselves with the instructors, they were familiar enough with it to guide groups of current students. However, using undergraduate facilitators is not necessary, so long as this is not the class' first exposure to active learning and the instructors are comfortable and willing to oversee multiple groups at a time, since the groups are given clear instructions for each component of the activity and can for the most part function autonomously.

INTENDED AUDIENCE

This lesson is intended for undergraduate students majoring in the biological sciences, allied health sciences, pharmacy, nutrition, biomedical engineering, pathobiology, physical therapy, or occupational therapy. This lesson was taught to primarily sophomores and juniors studying the health sciences. While we include specific supporting materials, our lesson is broad; alterations can be made to tailor the plan to a more or less advanced audience as necessary. In more advanced courses, greater emphasis could be placed on pharmacological mechanisms, side effects, and pathology. In a lower level course, more emphasis could be placed on anatomy and histology. Our activities were completed by groups of five or six students, which we believe is an optimal number to promote collaboration and active learning among all participants. Given that our course is large, we randomly assigned students to a group prior to class using the "Groups" feature in our LMS. Groups could also be formed spontaneously in the class between nearby students, or, in a smaller course, hand picked to promote interactions between higher and lower performing students. As a variation, activities could be replicated with larger groups with space constraints by using a think pair share format. Even online courses could likely replicate most elements using given access to a virtual chat or discussion board.

REQUIRED LEARNING TIME

This lesson was given in place of a traditional fifty-minute lecture period covering the same material. While concepts were covered thoroughly in the lesson, students were asked to review the topics beforehand, primarily by viewing a pre-class video posted online (*see* Supporting Material S1: Regulation of Gastric Secretion video) and by completing a template of the gastric pit (*see* supporting material S2: Blank Gastric Secretion Template). This video, and the accompanying diagram, should take no more than twenty minutes to complete. The video offered a brief introduction into the different mucosal cells within the stomach, their secretions, and their role in the formation of hydrochloric acid. In totality, the lesson should take a around one hour for most students.

PREREQUISITE STUDENT KNOWLEDGE

Students should have a basic understanding of the anatomy of the GI system, including the four tissues layers. They should be familiar with the major features of the endocrine and nervous systems, and the spatial arrangement of the cells in the gastric pit (e.g. apical vs. basolateral membrane). Students should also be comfortable working with with terminology related to gastric secretion (*see* Supporting Material S1: Regulation of Gastric Secretion video).

PREREQUISITE TEACHER KNOWLEDGE

Instructors should be comfortable explaining the gross anatomy of the GI system, including how organs and structures are interconnected More specifically, instructors should be able to identify secretions from the gastric mucosa and match them to specific mucosal cells and to their molecular mechanism of action. For example, instructors should know that parietal cells secrete Hydrogen and Chloride ions (H+ and C-, respectively) to form hydrochloric acid in the lumen of the gastric pit, and that histamine receptors on parietal cells are Gs coupled G-protein coupled receptors.

Instructors not familiar with the hierarchy of the GI system, the gastric mucosal cells and their secretions, or how hydrochloric acid is formed should review the pre-class video (*see* Supporting Material S1: Regulation of Gastric Secretion video). Facilitators or assistants should have thoroughly reviewed the case study presentation and associated notes (*see* Supporting Material S5: GI Case Study Presentation).

SCIENTIFIC TEACHING THEMES

Assessment

Learning is measured by student-reported assessments of learning gains and by scores on multiple choice exams. In preparation for the activity, students completed an online quiz on a GI case study. After the activity, reflective questions were provided to students, and concepts discussed in the activity were included on the next exam. Student comments and scores on relevant material are located in the teaching discussion.

Inclusive Teaching

This lesson is interactive, tasking students to work together to link, locate, and define structures within the GI system. The cooperative nature inherent in the small group format may increase student attention leading to an increase in learning gains (4). Further, because the activities rely on a visual-spatial element (drawing), students may see an increase in information recall compared to more conventional methods (5). Those often disadvantaged by traditional lecturing—who prefer to learn by seeing and doing rather than by listening—may benefit from the visual nature of the activities.

Students who learn in accordance with David Kolb's "Accommodating" learning style—those who benefit from feeling and doing—may particularly benefit from our lesson. Such students, as described by Kolb, are most suited for concrete experiences coupled with active experimentation (6). Throughout the lesson, students are tasked with drawing (a concrete experience) as well as interpreting and assessing scientific data (active experimentation). In our course, as in most A&P courses at this level, some of the content introduced by the activity (e.g. the pharmacology) is novel to students. This should place students on equal footing at the beginning at the activity, and prevent prior knowledge from life or academic experience to give an advantage relative to their peers. Moreover, if desired, there are optional questions included in the case study to have students look at ethnic variations in ulcer susceptibility, as well as the intersection of health and socioeconomic status (e.g. an ulcer patient without health insurance might rely more on less efficacious over the counter treatments like antacids, whereas someone with health insurance would presumably have access to proton pump inhibitors, calcium channel blockers, and antibiotics).

LESSON PLAN

Pre-class preparation

In designing this activity, we tried to use common, inexpensive materials so that the lesson was accessible to all; most of the pre-class preparation consists of gathering and organizing materials already available to instructors. Instructors should have pens or markers, as well as large, poster-sized pieces of paper available for each group. These can be purchased at an office supply store or through online retailers like Amazon. The total cost for running the activity for 400 students was under $20. Students will use these to connect the major structures of the GI system with the cells or cell components they contain and the molecules they secrete (*see* Supporting Material S4: GI Concept Map Instructions). While not required, sticky notes were helpful in our activity—students could write out each component on a sticky note, place it on the poster paper, and draw arrows connecting them to others. If mistakes were made, the sticky notes could be rearranged, obviating students from having to cross out their errors. Instructors should have the case study presentation (*see* Supporting Material S5: GI Case Study Presentation) loaded onto computers for each group, and a facilitator or designated student to present the Powerpoint. If class computers are unavailable, students can be asked to bring personal laptops to the activity. Alternatively, instructors can present this case study in a traditional lecture setting, and ask for volunteers to answer the embedded questions. Instructors will need a template of the gastric pit (*see* Supporting Material S2: Blank Gastric Pit Template) or analogous template.

Students should be familiar with the concepts discussed in the pre-activity video (*see* Supporting Material S1: Regulation of Gastric Secretion video) and have completed the pre-class template (*see* Supporting Material S2: Blank Gastric Pit Template).

LECTURE

Previous lecture material

Before this activity, students attended a lecture presentation on the anatomy of the digestive system, and given an overview of the major GI processes (secretion, absorption, motility, digestion).

Set-up:

The lesson set up involves preparing the poster paper, gastric pit templates, and case study presentations. Instructors or assistants should distribute these materials to students before or upon their arrival to class. If students are to work in groups, their work areas should be labeled with a group number or letter (e.g. Group 5) to prevent confusion at the beginning of class

In groups: When students arrive, they will meet at a table or area clearly labeled with a letter or number that they were assigned. Instructors or facilitators will introduce themselves, and give each student a copy of the concept map activity sheet (*see* Supporting Material S4: GI Concept Map Instructions), after which students will begin to link all the related structures. At this time, students are advised to write out the components on sticky notes before placing them on the poster paper and drawing arrows or lines to connect the terms. It is important that, while the facilitator should answer student questions, he or she should not take a central role in determining how to organize the concept map—inherent in the success of the concept map is that it allows students to work independently and develop novel frameworks with which to organize material.

When students have completed their concept map, the facilitator should inspect it and probe the group's understanding. For example, a facilitator might ask why the group connected Parietal cells to Hydrochloric acid, after which students should indicate that these cells secrete HCl. If the students are incorrect or unsure, facilitators should offer the correct answer and then explain why. Secondarily, if a secretion affects another component within the concept map, it is important to indicate that as well. After the concept map has been reviewed, group members should see how seemingly disparate cells work together to accomplish their function.

After completing the concept map, students will label a blank gastric pit with the relevant structures (*see* Supporting Material S2: Blank Gastric Pit Template). Facilitators will have a completed gastric pit available to reference if the group needs clarification (*see* Supporting Material S3: Completed Gastric Pit Template). As before, it is the facilitator's job to assess the group's understanding. He or she may ask what the consequences of inhibiting the H/K/ATPase

(Proton Pump) would be, or how increased cAMP concentrations would affect signaling pathways. For examples of facilitator questions, *see* Supporting Material S6: Facilitator Question Prompts.

Students will then be asked to research the pharmaceuticals found on slide 7 of Supporting Material S5: GI Case Study Presentation. (This can be done on their cell phones, tablets, laptops, or, if desired, a group computer). Using the same template as before, students will apply their understanding of ion channels and transporters; either verbally or by drawing the structures on the template, the group will assess the effects of these drugs. How will Pantaprazole, for example, affect the pH of the stomach lumen? Is it inhibitory or stimulatory? Facilitators should inquire into how these drugs might be used in a clinical setting in order to link the course material to the real world.

For our course, we impressed upon the students that the names of these drugs were ancillary concerns and that the value in the lesson was to focus on the mechanism. The purpose of introducing pharmaceuticals here is to relate course material to real life and to, broadly, identify the consequences of inhibiting or stimulating different ion channels or transporters. On an exam or assessment, the name of the drug would be coupled with a description of how it works, and the student would be asked to evaluate the effects of the inhibition or stimulation on the body. Interestingly, given the common incidence of gastric ulcers, many students were already familiar with some of the medications, which provided additional avenues for discussion within the groups.

Lastly, students should proceed to the case study presentation on gastric ulcers (*see* Supporting Material S5: GI Case Study Presentation). Given that the causative agent is revealed at the presentation's conclusion, facilitators should not correct students when they answer the embedded questions incorrectly. Rather, they should ask why the group believes an answer is correct, and explain the correct choices at the end. This problem-based learning (PBL) not only helps to hone skills in analysis and research—it helps broaden an understanding of scientific practices (7). In this case study, we extend beyond a discussion of the pathology of peptic ulcers; we present experiments, their results, and crucially, examine how science adapts to new information. The very process of interpreting results from the case study is helpful in informing students of the scientific method.

TEACHING DISCUSSION

Lesson effectiveness

Students and facilitators alike remarked that the activity was engaging and intellectually stimulating. Of note, several respondents indicated that the activities were helpful in moving beyond simple memorization of course material. One such respondent wrote: "I found the small group activities to be incredibly helpful. Having a few students to discuss any confusion with, along with the very informative facilitators provided a great learning environment. It can be easy to zone out in lecture and miss important information, but in this small setting it was far more engaging and made comprehending the information, not just memorizing it, much easier."

An unintended but welcome consequence of the activity was that students felt more comfortable asking questions—and having them answered—in the group setting. Large lecture classes are intimidating, and while we stress early on in the course that students should raise their hand if they need clarification, it is nonetheless an action fraught with anxiety. As recorded by a student: “The group activities allow the class to be a bit smaller. Sometimes I don't want to ask questions in class because I fear it will cause the class to get behind on lecture (also I feel the questions I ask might be stupid, or pointless). That said, the group activities allow my questions to get answered, and to be sure the concepts are drilled in my head.”

Student reactions

In more formal assessments of perceptions, acquired through a “wrapper” survey at the end of our course, students responded positively about the activities. We sought feedback from the 124 students enrolled in Section 30 (experimental section) and 122 of them responded to the online survey. While some students (<5%) expressed disappointment with the activities, the overwhelming majority indicated they not only enjoyed them, but benefitted from them. Students who described themselves as visual learners were particularly drawn to the activity. As one respondent noted, “It helped create a visual memory of the information that was a lot easier to recall then just looking at my lecture notes”. Similarly, another student said: “I am more of a visual learner, so being able to see the diagrams drawn out, helped me to connect different topics and how they related to each other. I think this should continue [in the future].”

Some students, though, did find faults within the activities. One student found that “Researching the drugs did not help me understand the material better”, while another felt that the activities were not specific enough and “ [did not provide] information related to study material”. In other words, the fluid discussions and problem solving did not offer enough tangible study materials to refer back to after the activity.

Lecture settings:

If instructors cannot break the class into smaller groups, or find assistants or facilitators to lead groups, it is possible to work through some of these activities in a traditional lecture format.

In this instance, the concept map could be drawn on a whiteboard or projector by the instructor, who would ask students to raise their hands and offer suggestions on how to connect the terms. Similarly, the gastric pit template could be instructor-drawn but student-created; the instructor could place an ion channel on the template and then ask students to describe its function. The case study presentation would be most easily transposed into a traditional lecture format: the embedded questions could be answered by individual students raising their hands, or by students working with their "neighbors". In these instances, the material list and number of required assistants may be less prohibitive.

In a large lecture setting, however, there is likely to be less student engagement, a crucial factor in the success of our activity. Similarly, since the concept map would be created by multiple students, its organization would not be unique to each student. The cooperative nature of the activity—a key component cited by students for its success—is lost if it is completed in a large group.

SUMMARY

We present this lesson plan as a simple and effective alternative to teaching the principles of regulation and secretion within the gastrointestinal system. In developing concept maps and diagrams, students achieve a unique framework with which they can organize material. Direct visualization of the material and an active role in creating this content helps with retention. To our surprise, we lost very little "content" by teaching the class this way. This, paired with the general student enthusiasm, has given us momentum to develop similar activities for future units.

Acknowledgments

The authors wish to acknowledge funding from the Large Course Redesign Grant initiative from the University of Connecticut's Center for Excellence in Teaching and Learning (to JMR) and the Honors Program (to JWD). We also wish to thank Dr. Radmila Filipovic, Mr. Fred Murphy, and Mr. Shanu George for their assistance and feedback during the development of the activity.

References

1. National Research Council (US) Committee on Education on Dual Use Issues in the Life Sciences. Challenges and Opportunities for Education About Dual Use Issues in the Life Sciences. Washington (DC): National Academies Press (US); 2010. 2, A Primer on the Science of Learning.

2. Palis, A. G., & Quiros, P. A. (2014). Adult Learning Principles and Presentation Pearls. *Middle East African Journal of Ophthalmology*, *21*(2), 114–122. http://doi.org/10.4103/0974-9233.129748

3. Washington, DC, in July 2009 for the AAAS Vision and Change in Undergraduate Biology Education summit, calling for relevant, outcome-oriented, active biology learning focused on deep conceptual understanding in student-centered environments with ongoing feedback and assessment (Woodin, Carter, and Fletcher 2010; Brewer and Smith, in press).

4. Jan G.M. Kooloos, Tim Klaassen, Mayke Vereijken, Sascha Van Kuppeveld, Sanneke Bolhuis & Marc Vorstenbosch(2012) Collaborative group work: Effects of group size and assignment structure on learning gain, student satisfaction and perceived participation, Medical Teacher, 33:12, 983-988, DOI: 10.3109/0142159X.2011.588733

5. Wammes, J. D., Meade, M. E., & Fernandes, M. A. (2016). The drawing effect: Evidence for reliable and robust memory benefits in free recall. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/26444654

6. Kolb, A., & Kolb, D. (2005). Learning Styles and Learning Spaces: Enhancing Experiential Learning in Higher Education. *Academy of Management Learning & Education*, *4*(2), 193-212. http://www.jstor.org/stable/40214287

7. Allchin, D. (2013). Problem- and Case-Based Learning in Science: An Introduction to Distinctions, Values, and Outcomes. *CBE Life Sciences Education*, *12*(3), 364–372. http://doi.org/10.1187/cbe.12-11-0190

SUPPORTING MATERIALS

S1: Regulation of Gastric Secretion Video (.video)
S2: Blank Gastric Secretion Template (GastricPit_Blank.pdf)
S3. Completed Gastric Secretion Template (GastricPit_Complete.pdf)
S4. GI Concept Map Instructions (GI_ConceptMap.doc)
S5. GI Case Study Presentation (GI_case.ppt)
S6: Facilitator Question Prompts (GI_QuestionPrompts.doc)
S7: GI Pre-Class Assignment (GI_PreClass.doc)