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Promoting Excellence in the Teaching of Human Anatomy & Physiology

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Lights, Camera, Action Potential: Student-Generated Videos in Online and Face-to-Face Physiology Education

Melanie Schroer, MS

Biology Program, School of Natural Sciences and Mathematics, Stockton University, Galloway, NJ, USA

Corresponding author: Melanie.Schroer@stockton.edu

Abstract

Student-generated videos (SGVs) are gaining popularity and have been increasingly incorporated into undergraduate curricula in many disciplines. Through the creation of their own educational digital videos, students learn course content and transferrable skills. However, the use of SGVs in anatomy and physiology (A&P) is virtually undocumented. In this mixed-methods study, students in online and face-to-face A&P courses independently created short videos about relevant physiological phenomena. The results indicate that perceived and actual learning, as well as enjoyment, were positively impacted by the creation of the SGVs. Though it was not required, students watched their peers' videos over 12,000 times in the online course and over 1,100 times in the face-to-face course. These findings demonstrate the value of SGVs in the A&P lecture classroom for the first time. https://doi.org/10.21692/haps.2024.001

Key words: student-generated video, prosumer, online, physiology education

Introduction

Though anatomy and physiology (A&P) courses are often a prerequisite for continuing in various allied health majors, students often struggle to succeed. Across gender, ethnicity, class standing, and academic major demographics, all groups of students perceive A&P as difficult or a "killer class" (Keller & Hughes, 2021; Lunsford & Diviney, 2017; Sturges & Maurer, 2013). Thirty to fifty percent of students fail, drop, or withdraw from these courses (Keller & Hughes, 2021; Sturges & Maurer, 2013), with the lowest grades correlating with a heavy courseload, outside employment, and/or insufficient science readiness (Harris et al., 2004). Fortunately, pedagogical shifts have been shown to improve the success rate, especially among students who find the course to be extremely difficult (Lunsford & Diviney, 2017; Sturges & Maurer, 2013).

Video, as one such pedagogical innovation, has proven to be an effective medium for teaching in A&P courses. Commercially produced dissection videos were first incorporated into the classroom with the increasing popularity of the VHS in the 1980s and became used more widely with the invention of CDs in the 1990s. With the development of YouTube in 2005, students now have access to a new source of video material (Hulme & Strkalj, 2017). Through evolving video technology, students can learn dissection techniques and study prosections without being physically present in the classroom. When required to watch professional instructional laboratory videos, students performed significantly better on assessments (Hulme & Strkalj, 2017; Mutch-Jones et al., 2020), and reported a higher level of confidence and comprehension (Mutch-Jones et al., 2020). Many courses offer dissection videos merely as a supplement to in-class instruction (Hulme & Strkalj, 2017). The use of publisher videos has expanded considerably as the high production and consumption costs (i.e., video cassettes and DVDs) have declined and the speed and capacity of the internet have expanded (Laaser & Toloza, 2017).

In addition to publishers' videos, A&P instructors have incorporated self-produced videos into their courses. With today's ubiquitous access to technology with video capabilities and digital platforms for posted content (e.g. YouTube and learning management systems), instructors can produce video content tailored to the needs of their students in both laboratory and lecture courses (Hulme & Strkalj, 2017). For example, instructors have created instructional lab videos to offer instruction during weather-related school closures (Rudolph et al., 2018). Miller (2014) found when a traditional lecture was replaced by a short instructor-made video, the class average on a relevant assessment increased by six percent, with the largest influence on at-risk students in the class. Even when instructional videos were offered as an optional supplement to the course, students who watched the videos scored significantly higher on the exam (Saxena et al., 2008).

While expert videos have been an important part of maintaining quality instruction through the pandemic, they are yet another variation of traditional instructor-centered pedagogy. Instead, higher education has shifted in recent

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years from instructor-as-information-transmitter methods to adopt the constructivist framework of pedagogy, in which students actively take the primary role in formulating their own understanding (Epps et al., 2021; Navio-Marco et al., 2022). Thus, many educators have transferred the responsibility of digital content creation to their students. This approach assumed that students, while producing the videos, must synthesize and internalize relevant information before communicating their deep understanding to others. For example, the creation of student-generated videos (SGVs) has been perceived positively among students enrolled in business, liberal arts, and STEM programs (Epps et al. 2021). Immersing themselves in the creative process of producing an academic video has been shown to improve learning outcomes across disciplines (Bakla, 2018; Gallardo-Williams et al., 2020; Greene & Crespi, 2012; Pereira et al., 2014; Ryan, 2013; Stanley & Zhang, 2018). Furthermore, these assignments have been shown to improve self-efficacy (Lichter, 2012), learner independence (Bakla, 2018; Navio-Marco et al., 2022), digital literacy, and many other cross-curricular competencies (Epps et al., 2021).

Although the benefits of SGVs are plentiful, their use in the human A&P classroom is nearly undocumented (Doubleday & Wille, 2014). In A&P classes, students may benefit from creating videos in which they articulate and demonstrate physiological phenomena, content which is notoriously challenging for undergraduates to understand. To compose such a physiological narrative, students must reference multiple, often multimodal, sources, eliminate extraneous information, carefully construct images, and plan the sequence of events (Epps et al., 2021). They must construct a mental model and understanding of the physiology and create a valuable artefact through their own unique lens (Navio-Marco et al., 2022). Compared to a live presentation in front of the class, creating a video requires more rehearsal via multiple "takes" and replays as well as edits to assess quality and accuracy (Greene & Crespi, 2012; Ryan, 2013). Therefore, this iterative process may promote generative, meaningful learning of the relevant A&P content.

In this study, students enrolled in online and face-to-face A&P lecture courses were required to use their personal electronic devices to create videos detailing physiological processes. The research questions of the present study are:

- RQ1: What are student perceptions of making and watching SGVs?
- RQ2: Does the creation of a physiology video improve student perceived and actual cognitive learning?
- RQ3: Do SGVs promote engagement in face-to-face and online A&P courses?

The data presented here, which will document the use of SGVs in human A&P courses for the first time, are expected to suggest that students view these assignments positively, and that the videos can increase self-efficacy, academic performance, and engagement.

Materials and Methods

This project was approved by the Institutional Review Board of Stockton University, and informed consent was obtained from all participants. Students completed the following activities with the entirety of the class, regardless of the decision to participate in the study. Data were collected in three semesters (Spring 2021 A&P I; Fall 2020 and Fall 2021 A&P II).

Anatomy and Physiology I

SAMPLE

The subjects of this research were undergraduate students enrolled in an online course in A&P I for Health Sciences at Stockton University during the spring semester of 2021 (n=33). Most students were female (87.9%) and 3.0, 42.4, and 54.6% were of sophomore, junior, and senior status, respectively. All students were Health Science majors, with the exception of one Biology major and one Undeclared. Health Science majors have limited background in science, as their curriculum requires a single laboratory science, Chemistry I, prior to enrolling in A&P I.

ASSIGNMENT

As part of the standard Unit 1 curriculum for this course, the instructor used instructional slides and blackboard illustrations to introduce all students to two cellular physiology topics: protein synthesis and continuous action potential propagation. After the lessons, students were instructed to independently create a video-based explanation about one of these processes. The following general instructions were provided for all student videos:

- Include a diagram. You may narrate a diagram you have drawn or modified from a published source. You may NOT use my drawing directly from the lecture!
- You will earn the most points for speaking about these events in your own words, fluently and without simply/monotonously reading from your notes (see attached rubric for more details). Therefore, you should practice before you record, and become very familiar with the process. (This repetition will help you to learn the process in preparation for the upcoming Exam 1!)
- Videos should be less than 5 minutes long.

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Half of the class created videos on protein synthesis, and were given the following additional instructions:

- Begin your story with transcription of the mRNA. End your story with exocytosis of a vesicle from the Golgi apparatus.
- Be as thorough as possible, including abundant terminology (e.g. transcription, ribosome, etc.) and a coherent, chronological description of events. You are expected to use the level of detail presented to you on [date of lecture].
- In your telling of this physiological story, you must include a protein that is five amino acids long, and the DNA and mRNA sequences that code for it (don't forget the start and stop codons!). In other words, you will need the codon-amino acid chart! You may present your protein sequence like this: Met-Ala-Lys-Pro-Lys.

The second half of the class created videos on continuous action potential propagation, and were given the following additional instructions:

- Begin your story with the neuron at resting membrane potential (RMP); how does the cell maintain this charge? Your "story" should end with the "recycling" of acetylcholine (Ach).
- Be as thorough as possible, including abundant terminology (e.g. neurotransmitter, voltage-gated Na^+ channel, etc.) and a coherent, chronological description of events. You are expected to use the level of detail presented to you on [date of lecture].
- In your telling of this physiological story, you must identify different types of membrane transport: facilitated diffusion, active transport, and exocytosis.

Students submitted their videos to be viewed by the instructor via the learning management system, email, or a phone application which was formerly called *Flipgrid* (at the time of publication, it is called *Flip;* see below for more information about this platform). Student videos were not shared with the class, but individuals may have shared their work with their peers outside of class. The instructor provided detailed text or video feedback privately to each student prior to the summative assessment.

Assessment of Knowledge

All students were tested on their knowledge of content from Unit 1 of A&P I via an online, time-limited, multiple-choice-question exam. Embedded within the exam were ten instructor-written questions about protein synthesis and ten questions about action potentials; all questions were randomly ordered by the learning management system. Individual student performance on all 20 questions was recorded and classified according to which video prompt they used.

Anatomy and Physiology II

SAMPLE

The subjects of this research were undergraduate students enrolled in A&P II at Stockton University in the fall semester of 2020 (exclusively online, n=33) and the fall semester of 2021 (face-to-face modality, n=27). The online students were 84.8% female and 15.1, 48.5, and 36.4 were of sophomore, junior, and senior status, respectively. All students were Health Science majors except for one Psychology major. The face-to-face students were all Health Science majors, 81.5% female, and 29.6 and 70.4 were juniors and seniors, respectively. Regardless of modality, all students had earned a C or higher in A&P I, and sixteen students were among the A&P I population assessed above.

ASSIGNMENT

Both A&P II courses were divided into three units, each covering three organ systems or major topics. The content is heavily based in physiology and students are required to learn dozens of processes and clinical conditions within each unit. The instructor composed eighteen physiological prompts, such as:

- **Cookies in the Oven**: You smell cookies baking, but you are not yet able to eat them. What phase of digestion does this aroma induce? Explain what part of the brain and the autonomic nervous system are engaged by this experience, and what changes they trigger in the digestive tract. Be specific about motility, secretions, and hormones.
- **Respiratory System and pH Balance**: Describe how the respiratory system can be used to balance the blood's pH. Your explanation could compare the responses of the respiratory system to metabolic acidosis (maybe you just worked out and your muscles produced a lot of lactic acid) versus metabolic alkalosis (maybe you have food poisoning and are losing a lot of stomach acid via vomiting). You should describe the chemical buffer system that the respiratory system can modify and how hypo-/hyperventilation can shift pH.
- **Cellular Immunity**: Describe cellular immunity, including the cells involved, where they are created and/or "trained," how the cells are activated, and how they work to recognize and rid the body of a potential threat.

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The instructor created a SignUp Genius webpage (https://www.signupgenius.com/) to provide students with the opportunity to choose which prompt they would answer. Up to two students could sign up for each prompt. In addition to the prompts, students were provided the following instructions:

- Once you have signed up, you will compose a description which answers the prompt. You will use a visual (a relevant graph, diagram, image) that you have found or drawn yourself to aid in your description, and you will point out the relevant features during your video. Videos must be 2-5 minutes long and use relevant terminology accurately. The most credit will be awarded for descriptions which are fluent and written in the student's own words. The title of the video must be the title of your prompt as written below. You may take a selfie or a photo of your diagram for the tile image before submitting.
- This video will count as both a form of assessment (2% of your grade!) and a resource for studying. Once the videos are created, they will be available to your classmates so that you all may learn this diverse content. The video must be completed and submitted to Flipgrid by [date and time]. The instructor will provide private comments to the video creator and may annotate the videos so that the class is aware of particularly good descriptions or any inaccuracies.

Students submitted their videos to the Flipgrid phone application or website, where they could view their classmates' responses. Flipgrid tracks hours of usage and number of views for each video, which were documented as engagement for this study. This activity was completed for each of the three units in A&P II.

Assessment of Students' Perceptions

At the end of the semester, students completed a survey on Qualtrics (https://www.qualtrics.com/) about their perceptions of the video activity. They answered the following questions using a Likert Scale (1=Not at all true; 5=Very True):

- I enjoyed recording videos on Flipgrid very much.
- I enjoyed watching videos on Flipgrid very much.
- I was most confident about the processes that I described on Flipgrid.
- I learned a lot by watching my classmates' Flipgrid videos.
- On the exam, I was able to answer questions about my chosen topic because I made a video about it.

The survey also included the following open-ended question: "You may type any additional feedback on the lecture Flipgrid videos here."

Data Analysis

All data was analyzed using Microsoft Excel and ASTATSA Online Web Statistical Calculators for Categorical Data Analysis with a significance value of 0.05. See the Results section for specific tests performed.

Results

RQ1: What are student perceptions of making and watching SGVs?

The face-to-face students indicated significantly lower enjoyment of both recording and watching student-generated videos compared to the online students (Table 1). The average Likert scores for each question are nearly equal, but, in each class, 7 students ranked their enjoyment of recording higher than watching and 7 students ranked their enjoyment of watching higher (the remaining students responded with the same value for each experience, 19 online students and 13 face-to-face students). On the survey, one student discussed the value of watching other student-generated videos:

> ***"These assignments make it easier to understand some topics because it's other students discussing it so instead of just talking straight up they are more likely to break information down into pieces and sections that we can understand."***

RQ2: Does the creation of a physiology video improve student perceived cognitive learning?

Both online and face-to-face A&P II students indicated that making a video about a topic enabled them to answer exam questions (Table 1), although feedback from the online students was significantly higher than the face-to-face students ($p=0.005$, Mann-Whitney Test for discrete data). The students were also most confident about the processes they described in the videos they themselves made, with no significant difference between online and face-to-face students (Table 1). Compared to their feedback on generating their own videos, the average score for "I learned a lot by *watching my classmates' videos*" was lower, particularly in the face-to-face class (Table 1). Written feedback was consistent with the higher perceived value of creating the videos, though feedback was mixed. Sample responses are below:

> ***"Though recording the actual Flipgrid isn't my favorite, reviewing the topic thoroughly really helped me understand my topics."***

> ***"Flipgrids helped me so much for my personal topic but learning from others was difficult."***

> ***"The flipgrids were the most valuable assignment for this course. Taking the extra time to thoroughly learn and be able to explain a process excelled my learning. It also helped me learn other concepts easier as well."***

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Survey Question	True (4) or Very True (5) [% of class]		Neutral (3) [% of class]		Average ± Standard Deviation		p-value
	Online	F2F	Online	F2F	Online	F2F	
I enjoyed recording videos on Flipgrid very much.	42.4	25.9	45.5	37.0	3.42 ± 0.97	2.70 ± 1.17	0.023*
I enjoyed watching videos on Flipgrid very much.	48.5	25.9	39.4	25.9	3.39 ± 0.97	2.70 ± 1.35	0.023*
I was most confident about the processes that I described on Flipgrid.	84.8	12.1	74.1	14.8	4.24 ± 0.79	4.00 ± 1.11	0.545
I learned a lot by watching my classmates' Flipgrid videos.	63.6	21.2	25.9	18.5	3.67 ± 1.05	2.67 ± 1.14	0.001*
On the exam, I was able to answer questions about my chosen topic because I made a video about it.	90.1	9.1	66.7	14.8	4.61 ± 0.66	3.85 ± 1.13	0.005*

Table 1. *Student perceptions of student-generated videos in online and face-to-face A&P II classes (F2F = face-to-face). Mann-Whitney Test for discrete 5-point Likert Scale data. * indicates significance at α=0.05. Online 2020: n=33. F2F 2021: n=27.*

"Though I don't really like recording the Flipgrid videos, I do understand the content better after recording them. I don't view the other students' Flipgrid videos."

"I found that I knew a lot about the topic I chose for my flipgrid because I sat down and took time to go through that specific topic and learn details about it. I personally did not watch other peoples' flipgrid videos."

"The topics I chose to make the Flipgrid about definitely stuck with me the best and become the most recognizable topics on exams, quizzes, and other assignments."

"Some of the videos were hard to understand and made it a little more confusing."

RQ2: Does the creation of a physiology video improve student actual cognitive learning?

On average, students in A&P I scored significantly higher on exam questions about the topic of their own student-generated video. Students who created a video about protein synthesis scored 8.9% higher on protein synthesis questions than their peers who did not create a video on this topic (Figure 1, p=0.048, Mann-Whitney Test for non-normal distribution of scores). Students who created an action potential video scored an average of 9.5% higher on related exam questions compared to their peers (p=0.041, Mann-Whitney Test for non-normal distribution of scores). Individual students answered more questions accurately on the topic of their video (H_0 = with video – without video score = 0; p=0.002, 2-tailed one-sample t-test) regardless of topic (protein synthesis: p= 0.039, Mann Whitney Test for non-normal distribution of scores; action potential: p=0.029, Mann Whitney Test for non-normal distribution of scores).

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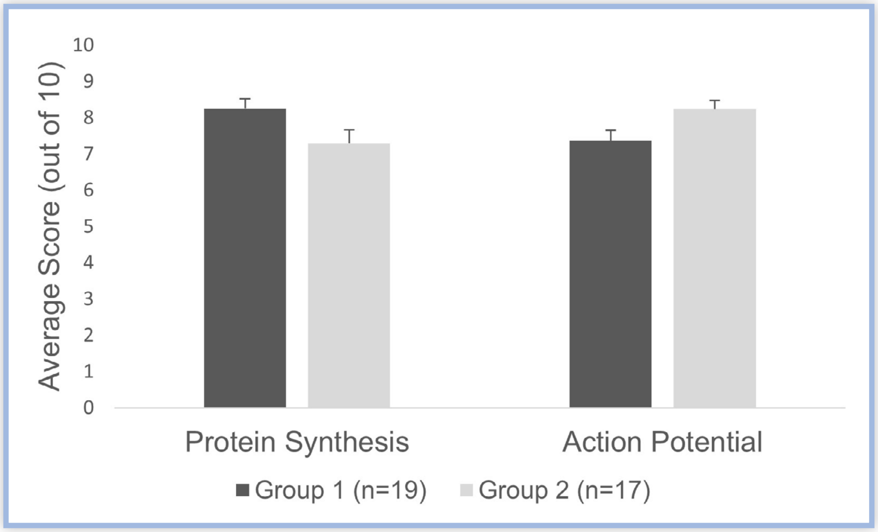

Figure 1. *Student-generated videos and accuracy on lecture exam questions. A&P I students in Group 1 (n=19) created a video about protein synthesis and Group 2 (n=17) created a video about action potentials. Average and standard deviation of student performance on ten questions about each topic is presented.*

RQ3: Do SGVs promote engagement in face-to-face and online A&P courses?

In A&P II, online students viewed the student-generated videos more often than the face-to-face students (12,375 vs. 1,111 views; 716.9 hours vs. 69.6 hours) (Table 2). Both classes engaged with the videos most in the beginning of the semester. In both the online and face-to-face classes, engagement was highest for unit 1 videos compared to unit 3 videos (195.56 vs. 76.29 views per video online, 24.62 vs. 4.5 views per video face-to-face).

Discussion

According to constructivist theory, when students are no longer merely consumers of content transmitted by educators, but instead, producers, they engage more deeply with course content to construct their own meaning and understanding (Navio-Marco et al., 2022). In this study, A&P students assumed the role of teachers and created valuable instructional videos (SGVs) on physiological phenomena. To create a video, students were required to not only research their topic thoroughly, but actively construct a sequence of events, carefully eliminate any extraneous information, and

	Online A&P II				Face-to-Face A&P II			
	Views	Videos	Hours	Average Views/ Video	Views	Videos	Hours	Average Views/ Video
Unit 1 Videos	6258	32	335.5	195.6	714	29	43	24.6
Unit 2 Videos	3752	31	239.5	121.0	280	26	16.2	10.8
Unit 3 Videos	2365	31	141.9	76.3	117	26	10.4	4.5

Table 2. *Student engagement with student-generated videos in online and face-to-face A&P II classes. Usage was recorded by the Flipgrid application, where these videos were posted. Views, hours spent watching videos by students, and average views/video for a unit prior to the relevant lecture exam. Note that the instructor watched each video once for grading purposes.*

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develop visual representations of the steps (Bakla, 2018; Epps et al., 2021; Gallardo-Williams et al., 2020). Although these methods may be required to develop a research paper or live oral presentation, the creation of a video has the intrinsic added value of repetition (Greene & Crespi, 2012; Ryan, 2013). That is, to be most successful, students had to compose a script, practice it, revise it, record their video, and finally return to their clips to correct or edit the content. In this study, one student stated, ***"Taking the extra time to thoroughly learn and be able to explain a process exceled my learning,"*** and another reflected, ***"I found that I knew a lot about the topic I chose for my [SGV] because I sat down and took time to go through that specific topic and learn details about it."*** Campbell et al. (2022) also noted that students spent abundant time with the content and that they "had to learn the subject matter to better teach it to someone else" (pg. 1150).

Creating a video enhanced perceived learning and self-efficacy. In both online and face-to-face classes, students indicated that they were most confident in their understanding of the processes they filmed and that creating a video on a topic helped them to answer exam questions on that topic. Lichter (2012) revealed a similarly positive perception of SGVs' value in preparing for a chemistry exam. Because females' lower self-efficacy is an important factor in the gender gap in STEM courses (Kalender et al., 2020), active learning exercises like SGVs may aid in promoting female students' success in STEM by increasing their self-efficacy. In contrast to the results of the current study, over half of the nursing students studied by Pereira et al. (2014) were neutral about SGVs improving their subject-specific competencies. Race, native language, economic status, first generation college student status, and incoming GPA may account for the variability in perceptions, as seen in work by Stanley and Zhang (2018). Therefore, future research should consider the influence of demographics, behavioral characteristics, and general academic competency on student perceptions of SGVs.

Not only was perceived learning increased after making an SGV, but actual student learning increased, as well. In this study, when A&P I students created a video explaining protein synthesis or action potential propagation, they scored significantly higher on relevant multiple-choice exam questions than their peers who did not create a video on that topic. While many studies on SGVs did not assess performance directly (Epps et al., 2021), those that did demonstrated a positive impact of SGVs on exam scores (Greene, 2014; Lichter, 2012; Pereira et al., 2014; Stanley & Zhang, 2018). Lichter (2012) revealed that learning is not only improved in the short term, but that chemistry students who made an SGV answered a question on the final exam more accurately than students who did not create a video.

Previous studies have suggested that SGVs may improve learning the most in students historically marginalized by the education system. Ralph et al. (2022) found that students without access to high-quality secondary education, particularly people of color, scored in the bottom quartile of traditional assessments. When the emphasis of a chemistry assessment was shifted, instead, to the mechanistic reasoning of phenomena, the equity gap decreased by about 10% and the predicted pass rates of the marginalized students increased from 75 to 93%. Huang et al. (2020) noted that low-achieving students' pretest scores were significantly lower than their peers' scores, but after creating a video, there was no significant difference in scores.

In the sample studied here, students entered A&P classes with a scant science background. In Anderton and colleagues' (2016) analysis of over 400 A&P students, previous math and science exposure was significantly linked to performance in A&P. Therefore, A&P SGVs, which inherently promote a more conceptual or mechanistic understanding of physiology, may also help to close the gap between groups of students (such as my students and others without extensive exposure to high-quality STEM education prior to A&P) and create more equitable access to education for all. Future research should disaggregate the data to explore SGVs through an equity lens.

Responses to the project differed between online and face-to-face students, though perceptions varied between individual students. Firstly, online A&P II students in 2020 reported a significantly higher level of enjoyment of both watching and recording the videos. Secondly, online students agreed with the statement "I learned a lot by watching my classmates' Flipgrid videos" significantly more than the face-to-face students. Thirdly, when SGVs were available to all class members, online students elected to watch their self- and peer-made videos over 12,000 times during the semester while the face-to-face students watched fewer than 1200 times.

There may be multiple factors influencing the difference between the two groups of students. First, the face-to-face students returned to campus for the first time after 18 months of exclusively online learning. During this time, students learned primarily through videos; synchronous classes were held by videoconferencing, asynchronous lessons and supplemental material were often delivered via video on the learning management software or social media platforms such as YouTube, and many classes incorporated video discussion boards or projects for the

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first time. The novelty and excitement of a new learning activity, such as that seen when an SGV podcast project was first introduced to an information technology class in 2006 (Frydenberg, 2008), had most likely waned after a year and a half of using video so often. A marketing class found an SGV assignment to be the most valuable in the course (Greene & Crespi, 2012), but video assignments and their use in face-to-face classrooms was not as common and new as in post-COVID education. Future research should assess trends in student perceptions of SGVs over time.

A second factor in the difference between classes may reflect students' sense of isolation during the COVID-19 era of online learning. SGVs have been used in online course discussion boards for decades to increase the sense of community in distance learning (Fehrman & Watson, 2020). At the beginning of the COVID-19 pandemic in spring 2020, the author's A&P I course reported that one of the best takeaways from an SGV assignment was the ability to see their peers (unpublished data). The online students in this study may have watched and enjoyed the SGVs more due to their isolation from their classmates, while the face-to-face students interacted in person with their peers multiple days every week.

Despite the differences in engagement between online and face-to-face courses, both groups of students accrued hundreds to thousands of views on content they were not required to watch. This high level of engagement may be explained by the perceived benefit of the experience, which included learning from their peers. The positive impact of watching SGVs was even more pronounced in the study by Pereira et al. (2014), who found that 97% of nursing students found watching SGVs to be useful. In their review of 29 SGV studies, Epps et al. (2021) highlighted the way student videos explained material in a relatable and understandable way for their peers, a sentiment reflected by one student in the current study who said, ***"…instead of just talking straight up they are more likely to break information down into pieces and sections that we can understand."*** Achievement itself has been improved by merely watching the SGVs rather than making them (Lichter, 2014), and the use of peer videos as a study resource has been shown to reduce cognitive load (Epps et al., 2021).

Although the engagement with the videos was high and, on average, students perceived their peers' SGVs as helpful, many students were also critical of the videos' value. Biochemistry students also reported learning much more from making their videos than from watching other SGVs (Ryan, 2013). In addition to the unclear explanations in some videos, students may have trusted the SGVs less, and therefore found less value in them, out of concerns over accuracy of the message (Bakla, 2018). Regarding the creation of SGVs, some students reported that they didn't enjoy recording the videos. Although they are regularly on social media, these students may feel fear, shame, and/or anxiety over presenting videos to their classmates as seen in Ryan (2013) and Pereira et al. (2014). Others reported a concern with the time required to both learn the technical aspects of video production and the generation of the product itself (Epps et al., 2021; Greene & Crespi, 2012). A lack of existing digital literacy has been linked to lower impressions of creating SGVs (Greene & Crespi, 2012; Epps et al., 2021).

Despite the few criticisms of the assignment, both making and watching SGVs has been shown to be beneficial to undergraduate students. In this study, perceived and actual learning, engagement, and enjoyment were all positively impacted by SGVs. Students scored significantly higher on exam questions testing the material they were responsible for presenting. Additionally, high levels of engagement and enjoyment were measured. Tangible student soft skills such as communication (Navio-Marco et al., 2022; Pereira et al., 2014; Ryan, 2013), project management (Ryan, 2013), and technological competency (Pereira et al., 2014) have also been shown to be improved through similar learning opportunities. Finally, SGVs can be used as formative assessments (Gallardo-Williams et al., 2020), maximize class time for discussions and activities (Lichter, 2014), and improve accessibility to learning (Gallardo-Williams et al., 2020).

Limitations

Participants in this study may not be a representative sample of all A&P students. For example, they were mostly female and had minimal science background. Although the sample size (n=93) was larger than in many studies of SGVs [see Epps et al., 2021 (biology studies ranged from N=19 to N=44) and Pereira et al. 2014 (nursing study with N=29)], a larger sample of the population would help to elucidate the effects of pandemic exhaustion, demographics, and other variables influencing the effectiveness of the activities. Future research may also consider a comparison of performance and retention in courses with and without SGVs. The researcher was also the instructor of these students; her enthusiasm for the assignment may have influenced the students' perceptions. Finally, learning outcomes were assessed only through multiple-choice questions on exams. Essays or case-study questions may have produced different results.

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Conclusions

These data collectively highlight the value of student-generated videos in the A&P lecture classroom. There is minimal research on SGV usage in anatomy laboratories (Doubleday & Wille, 2014), and these data may be the first published instance of this tool in A&P lectures. The process of creating a video about a physiological process was most valuable in that it encouraged students to learn through a constructivist framework, actively synthesizing concepts into a concise physiological story. Most students enjoyed the process, and even if they did not enjoy it, they recognized the value of the exercise in terms of perceived and actual learning. In fact, students scored significantly higher on exam questions about the topic of the videos they created. Furthermore, students engaged with their peers' SGVs and felt they learned from them, though this response was stronger among online compared to face-to-face students.

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About the Author

Melanie Schroer, MS, is an Instructor of Biology at Stockton University. Since 2015, she has taught primarily human anatomy and physiology to health science students, but also teaches general biology, endocrinology, and ecology to biology majors. In her spare time, she owns and operates an organic farm, supplying the community with sustainably raised poultry and pork products, and livestock feed since 2012.

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Evaluation of Supplemental Instruction in Human Anatomy and Physiology I Using Predicted Grades

Gilbert R. Pitts, PhD, Amy L. Thompson, PhD MT (ASCP), Michelle Rogers, MS, James F. Thompson, PhD MT (ASCP), Joseph R. Schiller, PhD

Austin Peay State University, Clarksville, TN, USA

Corresponding author: pittsg@apsu.edu

Abstract

Human Anatomy and Physiology courses are "gateway" courses that students must pass with high grades in order to proceed through their program of study. However, student pass rates are often low, resulting in students attempting the course multiple times and delaying their graduation. Supplemental instruction performed by peer leaders is one mechanism that has been used to increase student success. The goal of this study was to evaluate the effectiveness of peer-led supplemental instruction by comparing predicted and actual course grades. We learned that students predicted to earn a C achieved higher grades when they utilized supplemental instruction. While those students performed better than predicted, supplemental instruction did not improve ABC rates for the class. We conclude that supplemental instruction can be of benefit for some students. https://doi.org/10.21692/haps.2024.003

Key words: supplemental instruction, predicted grades, anatomy and physiology

Introduction

Human Anatomy and Physiology (HAP) courses are "gateway" courses at many colleges and universities in the United States that students must pass in order to proceed through their program of study. It has been reported that 450,000 students enroll in these courses annually (Human Anatomy & Physiology Society, 2020). These challenging courses are often taken during the freshman year; for example, Austin Peay State University (APSU) encourages pre-nursing students to take HAP 1 during their first semester of college. Several studies have presented evidence of the difficulties students face in HAP. One study reported that only 38% of students enrolled in HAP 1 received a score of C or better while another reported that 58.6% of first generation students earned at least a C (Hopper, 2011; Russell et al., 2016). HAP courses are unusual in that students may be in either STEM (science, technology, engineering and mathematics) or non-STEM programs. In general, the attrition rates in the non-STEM health sciences are quite high (57%) in comparison to those of the STEM biological sciences (45%) and the average for all STEM disciplines (48%) (Chen, 2013). The different attrition rates suggest that students enrolled in specific programs may need additional help to succeed in HAP.

Students often do not seem to be aware of the difficulties associated with gateway courses such as HAP. This was illustrated in a study of 1,210 students in which 19% earned less than a C but very few students predicted they would fall into this category (Sturges et al., 2016).

Several factors have been shown to be associated with student success in HAP. These include increased age, not taking a developmental reading, math, or writing course, and not repeating prior courses (Russell et al., 2016). Another study showed that the year taken (freshman or sophomore), high school GPA as well as math and verbal SAT scores were important predictors of HAP success (Rompolski et al., 2016). The wide variety of these factors and their interactions preclude the effective use of prerequisites for many gateway courses.

Peer-led supplemental learning (SI) workshops have been effective in increasing student performance in courses as diverse as introductory computer science (Biggers et al., 2009) and introductory accounting (Etter et al., 2000; Jones, 2013). One study reported the use of SI in several STEM subjects including introductory biology, general chemistry, organic chemistry, and precalculus (Peterfreund et al., 2008). A one credit supplemental section of HAP at the University of Southern Indiana resulted in 63% of the students earning a C or better, while only 38% of students without supplemental instruction earned a C or better (Hopper, 2011).

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The goal of this study was to determine if supplemental instruction increased student performance in HAP at our institution, APSU. Our study is unique in that we compared the predicted and actual grades of students enrolled in supplemental and traditional instruction. Supplemental instruction carries the risk that students perceive it to be a form of remedial education; hence, they consider SI to be stigmatized. Therefore, supplemental instruction sections were renamed as “Success” sections. Enrollment in these sections was completely voluntary in order to reduce any stigma that might be associated with the course and to develop a learning community comprised of students with different amounts of preparedness.

Materials and Methods

Experimental Groups

Traditional and Success sections were created for three instructors. Each instructor taught at least two sections of HAP I: a Traditional and a Success section. The students enrolled in the Success sections attended the same lectures as those enrolled in the Traditional sections, resulting in combined courses containing up to 99 students. Each Success section consisted of no more than 24 self-selected students. Academic advisors were told that the SI sections were geared towards developing learning communities within HAP with the goal of increasing student success. Furthermore, they were told that we wanted students to take the class if they were concerned about HAP prior to registration so that students would understand the function of the Success sections. Since students enrolled in the Success sections prior to the start of class, they were already aware of the schedule and could ensure that they did not have any scheduling conflicts that would prevent them from attending the Success sections. Students in Traditional and Success sections were told that lecture attendance was mandatory; however, they were not penalized for missing class.

Instructor A taught 9 courses between Fall semester of 2013 and Fall Semester of 2018. Instructor B taught one course Fall semester of 2014. Instructor C taught one course Fall semester of 2016. In total, 422 students were enrolled in the Traditional course and 285 were enrolled in the Success course.

Students in all sections taught by a given instructor were graded using the same tests in an identical manner, regardless of whether the student was enrolled in a Success section or not. Instructors administered five tests covering specific sections of the course material and one comprehensive test. Tests consisted of multiple-choice questions and, in some sections, short answer questions. Tests were completed within the class period. Students in the Success sections received additional instruction by an undergraduate structured learning assistant (SLA).

SLA Selection & Training

The SLAs were selected by the course instructors and were required to have grade point averages of at least 3.0. Instructors selected SLAs from a pool of students who recently successfully completed HAP I and II. In general, these students had earned A’s during both semesters of these courses. In addition, it was important to utilize SLAs who improved over the course of the semester in which they were enrolled in HAP. This was thought to identify SLAs with more empathy and experience in grade improvement. Essentially, they could describe the changes that they made to improve their performance in HAP. The SLAs were then invited to meet with the instructor for an interview. The interviews were performed to examine the following factors that were used to select the SLA.

1. Motivation to be an SLA
2. Concern/empathy of the SLA for the HAP students
3. Ability of the SLA to interact with a diverse student population
4. Whether the SLA’s schedule fit with the HAP course schedule
5. Whether the SLA understood the importance of HAP to career goals
6. Whether the SLA was able to recall information about HAP

Once hired, the SLAs received two days of training in classroom management, communication skills, cultural awareness, ethics, and safety, as well as how to serve students with disabilities from the Student Learning Resource Center at APSU. The SLAs also met with the course instructors to learn about expectations and to discuss how the Success sections would be conducted. SLAs were required to attend each lecture session so that they knew what topics were being covered in class and how the material was presented.

Students enrolled in the Success sections were charged a fee of $75. This fee was used to pay the salary of the SLAs. The starting pay of the SLAs was $15/hour. They were paid for attending lectures, preparing for each SLA course, meeting with the instructor, and teaching their courses.

Success Section Course Design

Each Success section met once each week for 55 minutes. The SLA was responsible for SI class planning. However, there were few differences in course design amongst the SLAs because they utilized course materials provided by the previous SLA. Therefore, the biggest difference from one SLA to another was found in presentation/speaking style. Preliminary attempts at conducting Success sections clearly demonstrated the importance of Success section attendance. Therefore, students enrolled in the Success sections were required to attend

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each meeting. Any student that missed three Success section meetings was told that they would be awarded an absence-related failure (FA) for the final course grade.

At the beginning of the course, SLAs described the methods that they themselves used to successfully pass the course. This included discussion of study and test-taking strategies. Later, the SLAs reviewed course materials, answered student questions, and worked to engage students in small group discussions. SLAs were encouraged to keep the students engaged by asking them questions to encourage participation. Sometimes, the SLAs divided the class into groups and played online HAP quizzes. Each success section met two to three times between successive exams. After each exam, the SLA would discuss the exam and explain the answers to commonly missed questions.

Statistical Analysis

Predicted grades were computed for all students using Degree Compass (Denley, 2012; Whitten et al., 2013). Unfortunately, Degree Compass is proprietary software and the specific criteria and algorithm that it uses to predict grades have not been made available. It has been stated that Degree Compass uses a model that "combines hundreds of thousands of past students' grades with each particular student's transcript to make individualized recommendations for current students" and that it "uses predictive analytics techniques based on grade and enrollment data" (Denley, 2012). Degree Compass is currently packaged within Desire2Learn. The Desire2Learn features guide states that it utilizes "two elements: a degree audit for current students and academic histories of the school's students, including transcripts and test scores over the past 10 years" (Desire2Learn, 2013). I have been led to understand that the academic history includes High School GPA, ACT scores, and historic grades.

APSU utilizes an A, B, C, D, F grading system with no provision for +/-grading. Furthermore, the predicted grades obtained from Degree Compass did not estimate +/- grades. Predicted and actual grades were coded by numbers with F=0, D=1, C=2, B=3, and A=4. The difference between the predicted and actual grades was also calculated (actual grade – predicted grade). Hence, a difference of -1 would mean that their actual grade was one letter grade lower than the predicted grade. All statistical tests were performed using the General Linear Models (GLM) procedure of the SAS/STAT software package, version 9.4 (SAS Institute Inc, 2013). When needed, multiple means were compared using Duncan's tests (Duncan, 1955).

This project was approved by the Institutional Review Board of APSU (#17:017).

Results

We began by examining whether the students enrolled in the Success and Traditional courses were different; that is, whether students enrolled in the Success sections were predicted to achieve lower success than those in the Traditional sections. The average predicted scores of students enrolled in Traditional and Success courses were 2.386 ± 0.038, n=422 and 2.316 ± 0.043, n=285, respectively, and were not significantly different between the two student populations. The distribution of predicted grades of students enrolled in the Traditional and Success courses is presented in Figure 1. The number of students predicted to earn A's in the Traditional and Success courses was significantly different ($p<0.05$); however, there were no other differences amongst the distributions. Therefore, the students enrolled in the Success and Traditional courses were predicted to perform similarly.

In order to determine if participation in Success classes impacted course grades, an analysis was performed on the difference between final and predicted course grades (final grade – predicted grade; Fig. 2). A difference of -1 would mean that the student's actual letter grade was one less than their predicted letter grade. Students enrolled in both Traditional and Success sections received grades that were lower than predicted (Traditional: -0.543 ± 0.049, n=422; Success: -0.326 ± 0.0597, n=285). However, students enrolled in the Success sections had a smaller difference than those enrolled in Traditional sections ($p<0.05$), showing that the Success sections were related to student performance. The effect of instructor was also significant ($p<0.05$).

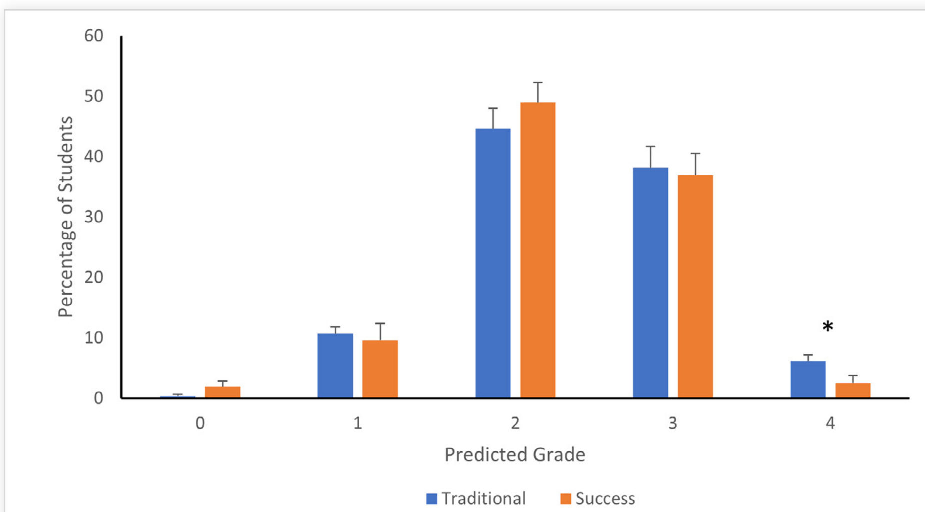

Figure 1. *Distribution of predicted scores of students enrolled in Traditional and Success courses. Data are presented as mean ± standard error. The asterisk denotes a statistically significant difference (p<0.05).*

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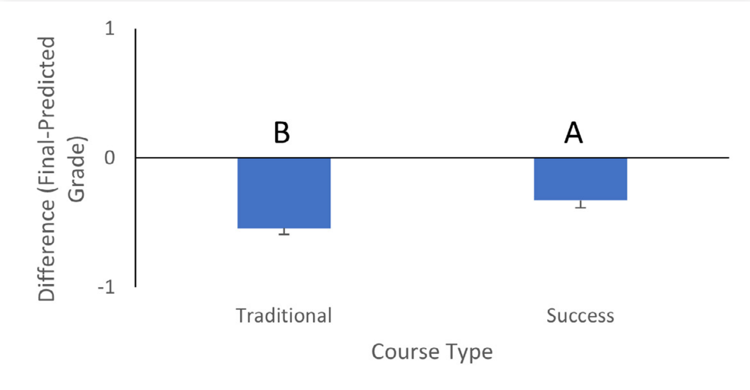

Figure 2. *The differences between predicted and actual grades of students enrolled in Traditional and Success sections. A difference of -1 indicates that a student's actual grade was one letter grade lower than the predicted grade. Data are presented as mean ± standard error. Bars with different letters are statistically different (p<0.05).*

Since there was a significant effect of course type on the difference between predicted and actual grades, we decided to examine the difference between actual and predicted grades for each predicted grade (Fig. 3). The difference between the predicted and final grades significantly differed among students who were predicted to earn a C in the course (*p<0.05*). The difference in grade was -0.529 ± 0.081 for students enrolled in Success sections while it was -0.796 ± 0.075 for students enrolled in Traditional sections. The impact of Success sections was not significant for students that were predicted to earn A's, B's, or D's.

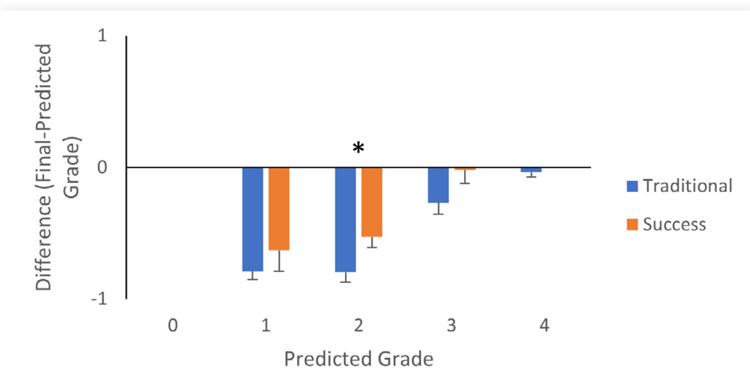

Figure 3. *The difference between predicted and actual grades at each predicted grade. A difference of -1 indicates that the student's actual grade was one letter grade lower than the predicted grade. Data are presented as mean ± standard error. The asterisk denotes a statistically significant difference between the Traditional and Success sections (p<0.05).*

Figure 4 depicts the actual final grade distribution of students predicted to earn a C. An important point about Figure 4 is that it provides some information regarding the ability of Degree Compass to predict grades. Specifically, it shows that if a student is enrolled in a traditional course and is predicted to earn a C, it is very likely that the student will earn a grade of C or lower. It is highly unlikely that they will earn an A or B.

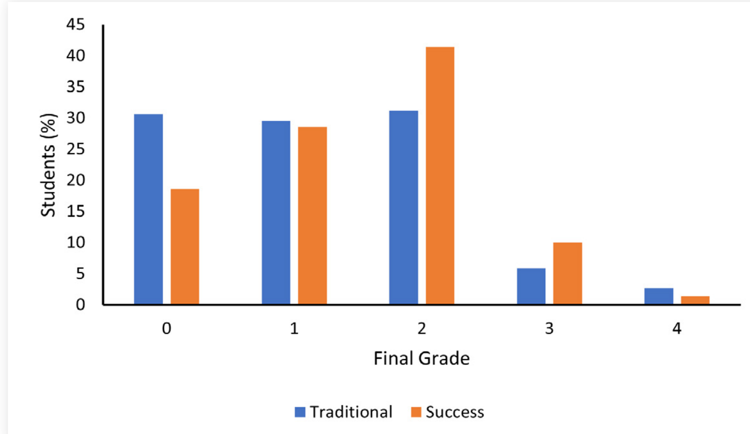

Figure 4. *The final grade distribution of students enrolled in Traditional and Success sections who were predicted to earn a C. Data are presented as mean ± standard error.*

Many colleges and universities use DFW or ABC rates as a metric to quantify course success. DFW is an abbreviation for the number of students who drop (D), fail (F), or withdraw (W) from the course. Figure 5 shows that there were no significant differences between the DFW and ABC rates of Traditional and Success courses (*p>0.05*). The DFW rates of Traditional and Success courses were 41.2 ± 2.4% and 36 ± 3.0%, respectively. ABC rates were 58.8 ± 2.4% and 63.8 ± 3.0% for Traditional and Success courses, respectively. These results show that implementation of success sections did not significantly impact the overall ABC or DFW rates.

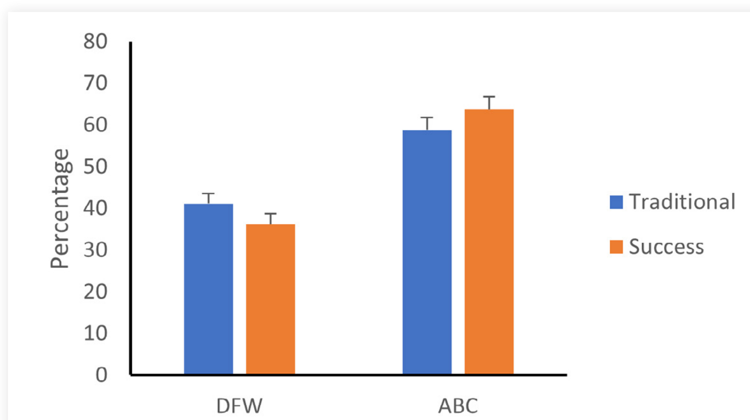

Figure 5. *DFW and ABC rates of students enrolled in Traditional and Success courses. There were no significant differences amongst DFW or ABC rates (p>0.05). Data are presented as mean ± standard error.*

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Although the overall ABC rates were not altered by the Success courses, we wondered what percentage of students might benefit from enrollment in the Success sections. To test this, we compared the percentages of students who increased, decreased or did not change their final grade in comparison to their predicted grades. These percentages are depicted in Figure 6. There was a significantly greater percentage of students who performed better than predicted in Success sections than in Traditional sections ($p<0.05$; Success: 20.6 ± 1.7%, Traditional: 13.7 ± 2.0%).

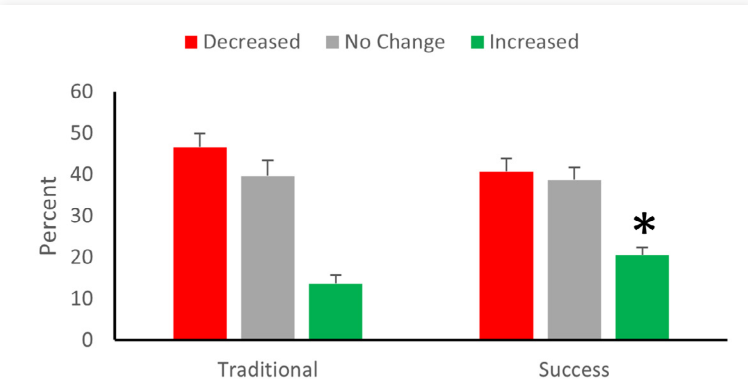

Figure 6. *The percentages of students who increased, did not change, or decreased their final grade from those of their predicted grades. Statistical comparisons were made between like groups and significant differences are marked with an asterisk (p<0.05). Data are presented as mean ± standard error.*

Next, we wanted to examine the accuracy of Degree Compass in predicting course grades. Therefore, we looked at the relationship between predicted grades and actual grades for students enrolled in both sections. The data for students enrolled in Traditional and Success courses are depicted in Figure 7. Twenty-seven students were predicted to earn an A in the Traditional courses; however, the average grade for these students was slightly lower (3.96 ± 0.037). Similarly, the 160 students predicted to earn a B earned slightly lower grades (2.73 ± 0.086). The actual grades of students predicted to earn a B was significantly lower than those predicted to earn a A (*p<0.05*). The actual grades of students predicted to earn a C were only 1.204 ± 0.075 (n=186) and those predicted to receive a D earned 0.213 ± 0.067 (n=47). The actual grades of students predicted to earn grades of C or D were significantly lower than those predicted to earn a B (*p<0.05*).

Eight students were predicted to earn an A in Success courses; these students all earned final grades of A (4.0 ± 0.). There were 107 students predicted to earn a B. The average grade earned in the course was slightly lower (2.98 ± 0.105). The actual grades of students predicted to earn a B were significantly lower than those predicted to earn an A (*p<0.05*). Of students predicted to earn a C, the earned grade average was only 1.471 ± 0.081 (n=140) and those predicted to receive a D earned an average 0.370 ± 0.161 (n=27). The actual grades of students predicted to earn grades of C or D were significantly lower than those predicted to earn a B (*p<0.05*).

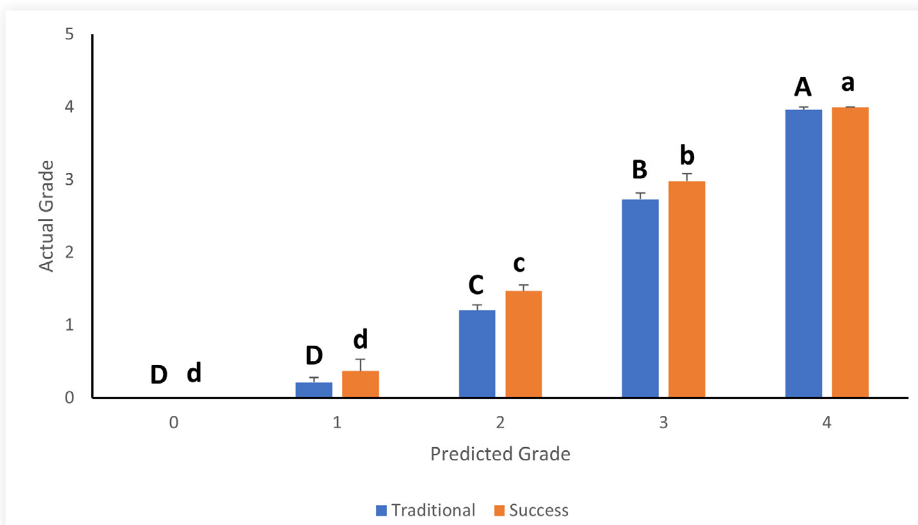

Figure 7. *The relationship between the predicted and the mean of actual grades of students enrolled in Traditional and Success courses. Bars with different letters are statistically different (p<0.05). Data are presented as mean ± standard error.*

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Discussion

Our results show that some students performed better when they were enrolled in Success sections even though ABC and DFW rates were not significantly altered. One factor that makes this study unique is that it utilized predicted grades for each student. Most experimental designs only show that one group of students performed better than another. The power of using predicted grades was that this method allowed us to examine the effect of Success sections on individual students. For example, we showed that students predicted to earn a C were aided by supplemental instruction. These students increased their grades by approximately one-half letter. The supplemental instruction used in the current study did not impact ABC or DFW rates. However, previous reports showed that SI was able to increase the number of students earning a C or higher (Rath et al., 2007). While our ABC rates were not affected by SI, our data clearly show that SI does alter the course outcome for the average (C level) student.

Since we utilized Course Compass to estimate predicted grades, we also examined its efficacy in predicting grades. Students predicted to earn A's and B's generally earned those scores. However, students predicted to earn C's and below often scored less than the predicted grade when enrolled in a traditional class. It was previously reported that Degree Compass is able to predict grades of at least a C within 0.56 of a letter grade; further, it correctly predicted who would earn at least a C 90% of the time (Denley, 2012).

At least one study found that SI instruction improved individual exam performance in both face-to-face and remote instruction courses (Rokusek et al., 2022). While we did not explicitly investigate the effect of SI on individual exams, we would expect to see a similar effect in this study because our course grades were only based on exam scores.

SI sections might be biased to have a larger impact on higher performing students (Jensen & Moore, 2009). However, a high performing student would already be predicted to earn an A or B. These students would be expected to already perform academic behaviors that allow them to do well in their classes (Moore & Jensen, 2007). In line with this reasoning, the current study showed that SI sections did not significantly increase the scores of students that were predicted do to well in the course. However, SI impacted the scores of students that were predicted to earn C's. This means that SI is able to make a difference for some students that need assistance such as review sections.

One may wonder if the students would be better served through the use of graduate student leaders. However, chemistry students recently rated trained undergraduate peer leaders higher than non-trained graduate student leaders (Philipp et al., 2016). Consistent with that finding, we try to utilize undergraduate SLAs rather than graduate students. Our graduate students work as graduate teaching assistants in lower level biology laboratories and are not involved in HAP lectures.

Student participation in supplemental instruction has been shown to be necessary to achieve a higher final course average (Hughes, 2011). For example, a calculus course with voluntary recitation attendance did not significantly reduce the DFW rate, while a mandatory course coupled with concept activities significantly reduced the DFW rate (Watt et al., 2014). Hopper (2011) showed that students who volunteered to attend SI in HAP outperformed their peers, but did not examine the impact of SI session attendance.

Prior to our study, we conducted two short-term trials (Pitts, personal observation). In the first trial, Success section attendance was voluntary during a summer semester course. Nevertheless, SI attendance was very high and there was a clear improvement in student performance. The model was repeated during the subsequent fall semester. Very few students attended the Success sections and there was no impact on student grades. Similar results have been reported in HAP courses, in which it was stated that students did not attend SI due to scheduling conflicts and to a lack of incentives (Hughes, 2018). Student attendance was later increased by providing extra credit for attendance and by scheduling the SI meetings early in the semester. Studies have also shown that supplemental instruction attendance increased Psychology 100 grades and that those with higher grades in that course were more likely to graduate (Paabo et al., 2021). In the present study, Success sections had an attendance policy that only allowed students to miss 3 meetings before an absence-related F was awarded for the course grade.

Student motivation is also important. Jensen and Moore (2009) revealed that students earning grades of D and F on their first exam rarely attended help sessions that were designed to prepare students for subsequent exams. They concluded that good students attended more help sessions, but that attendance did not turn students into good students. Our SLAs did their best to help with student motivation. However, student motivation and willingness to persevere in a course are probably more important than anything else that can be provided by the instructor or SI. It is possible that the students enrolled in the Success sections may have been more motivated than those in the Traditional sections, leading to volunteer bias. However, our data suggests that this was not the case since the predicted grades of students enrolled in the Success and Traditional sections did not differ.

SI has been shown to be particularly effective in assisting underrepresented groups. Rath et al. (2007) showed that SI increased the percentage of underrepresented students earning a grade of at least a C- more than for other traditional

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students. Similar effects were reported in other studies (Peterfreund et al., 2008; Thomas et al., 2019). SI instruction was found to be especially useful in improving the scores of male students (Peterfreund et al., 2008). The impact of Success sections on underrepresented groups was not examined in the current study as that type of demographic data was not collected.

This study focused on student performance. It did not examine student perceptions of SI. We did not request that students complete surveys of course satisfaction since the typical student would not be expected to describe their experience in a Traditional versus a Success course.

The results of this paper show that supplemental instruction increased the performance of students predicted to earn a C in HAP. This is very important to these students as they often seek admission into competitive programs such as Nursing that have high GPA admissions requirements. Further research needs to be performed to reveal methods that increase the performance of students predicted to earn less than a C in HAP.

About the Authors

Gilbert R. Pitts, PhD, is a Professor in the Department of Biology at APSU. He teaches Human Anatomy and Physiology I and II, Animal Physiology, Human Physiology, and Reproductive Physiology. His research is focused on the regulation of gonadotropin-releasing hormone secretion. Amy L. Thompson, PhD, MT (ASCP), is a Professor in the Department of Biology at APSU. She teaches Cellular & Molecular Biology, Anatomy & Physiology, and Introduction to Pharmacology. She researches the use of brown recluse spider venom as a pharmacological agent to kill cancer cells and the antimicrobial properties of plant products. Michelle Rogers, MS, is a Master Instructor in the Department of Biology at APSU. She received a master's degree in Science Education and has taught biology for over twenty years. James F. Thompson, PhD, MT (ASCP), is a retired Professor in the Department of Biology at APSU. He taught Human Anatomy and Physiology I and II, and Principles of Evolution. His research was focused on the intersection between laboratory medicine and nephrology. Joseph R. Schiller, PhD, is a retired Professor in the Department of Biology at APSU. He taught Human Anatomy and Physiology I and II, Conserving Biodiversity, Human Biology, and Zoological Diversity. His research interests include aquatic ecology and macroinvertebrates.

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A Qualitative Study on Instructor Experiences with Learning Objectives in the Basic Sciences

Kayla Pavlick, MS[1], Casey Boothe, PhD[2], Andrew Notebaert, PhD[3]

[1]School of Graduate Studies in the Health Sciences, University of Mississippi Medical Center, Jackson, MS, USA
[2]Department of Advanced Biomedical Education, University of Mississippi Medical Center, Jackson, MS, USA
[3]School of Interdisciplinary Health Professions, Northern Illinois University, DeKalb, IL, USA

Corresponding author: kpavlick@umc.edu

Abstract

While program-level learning objectives are required for medical school accreditation, session-level learning objectives are not, although many institutions use them. Most pre-clerkship basic science medical educators (PCBSMEs) do not have formal pedagogy training, so it is unknown when PCBSMEs learn about learning objectives or how they communicate them to students. A questionnaire was designed to phenomenologically explore these aspects during PCBSMEs' time as a student and as an educator. Qualitative data underwent inductive thematic analysis and generated two descriptive themes. Theme Educator Experiences describes how respondents learned about and used learning objectives as a student and as an educator. Theme Educator Communications describes how PCBMSEs communicate with students about using learning objectives. The relationship between themes suggest learning occurs following Bandura's Social Cognitive Theory. Findings indicate potential obstacles preventing implementation or communication about learning objectives, regardless of training. Strategies to proactively expose PCBSMEs to pedagogical concepts regarding learning objectives are recommended.
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Key words: learning objective, medical education, pedagogy training, thematic analysis

Introduction

The responsibility of pre-clerkship basic science medical educators (PCBSMEs) is to help prepare future physicians for their respective practice(s) by delivering foundational knowledge and promoting the integration of this knowledge across disciplines. Several factors have been identified as obstacles preventing PCBSMEs from carrying out this responsibility, including learning objectives that are poorly designed (DaRosa et al., 2011). Because learning objectives have been identified as an obstacle for PCBSMEs, this study aimed to investigate their knowledge and experiences with the use of learning objectives.

Definitions for learning objectives vary in the literature. One source describes learning objectives as a "statement that describes in specific terms what knowledge, skills, or attitudes learners should be able to demonstrate following instruction" (Webb et al., 2013). Different sources focus on student- or learner-centered statements of intention or goals (Chatterjee & Corral, 2017; Ferguson, 1998; Hartel & Foegeding, 2004) while others emphasize the measurability upon conclusion of the learning process as an indication of proof of learning (Alsheikh, 2020; Prideaux, 2001). Many sources freely interchange other terms with learning objectives including goals, competencies, or standards, but most often "objective" and "outcome" are found to be interchanged (Hager & Gonczi, 1996; Harden, 2002; McMahon & Thakore, 2006). As evidenced by a study investigating constructive alignment, "intended learning outcome" is frequently used with far less use of "objective" but no differentiation between the two terms was included (Wang et al., 2013). At their foundation, an objective is something toward which effort is directed whereas an outcome is the result of this effort and a retrospective concept.

The Liaison Committee on Medical Education (LCME) requires program-level learning objectives for allopathic medical institution accreditation in the United States (Liaison Committee on Medical Education, 2023). The intention behind using program-level learning objectives is to maintain standardization among medical education programs. These accrediting bodies provide generalized learning objectives at the program-level to guide curricular creation while the creation and inclusion of lower-level (i.e., session-level) learning objectives are left to the individual institutions (Association of American Medical Colleges, 2024; Kassebaum, 1992). By leaving this decision to be made by individual institutions, there is potential for session-level learning objectives to be excluded or substituted for other

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concepts like learning outcomes or program-level learning objectives. There may also be an increased variability in lower-level learning objectives since they are not regulated by an accrediting body.

Session-level learning objectives are also used to maintain curricular alignment by acting as a validation tool for assessments (Chatterjee & Corral, 2017; Ferguson 1998; McMahon & Thakore, 2006; Orr et al., 2022; Wang et al., 2013). Implementing high quality learning objectives at the session-level can increase the likelihood that the information provided to the student is what is truly being assessed. Educators that do not properly align learning objectives and assessment measures can create ambiguity, student misinterpretation, curricular misalignment, decreased student satisfaction, and instructor frustration (Alsheikh, 2020; Collier & Morgan, 2008; Leone et al., 2019). Therefore, it is critical for session-level learning objectives to be implemented in medical curricula to maximize curricular alignment. It is currently unknown how PCBSMEs implement session-level learning objectives in their courses, if at all.

Pedagogical training of PCBSMEs

According to the Association of American Medical Colleges' 2022 Faculty Roster, over 76% of PCBSMEs hold a PhD as their terminal degree (Association of American Medical Colleges, 2022). This means that the vast majority of teaching faculty within medical schools have likely received advanced training in their particular field of interest within the basic sciences, but may have had limited formal training in education prior to their faculty appointment. Many basic science doctoral students pursue a career in medical academia, which frequently comes with the responsibility of teaching (Association of American Medical Colleges, 2022). Yet, pedagogical training is often not a requirement for these teaching positions. Most basic science doctoral programs do not require courses in pedagogical practices, learning theory, or curriculum design. Rather, these programs focus on research wherein trainees gain an in-depth knowledge of one particular basic science area or field. Pedagogical training may often be optional or have limited availability to traditionally trained PhD students. For example, there are twenty-one anatomical doctoral programs in the United States but only eight of these programs formally incorporate education courses or training (Wilson et al., 2020).

The lack of formal pedagogical training may mean that few medical educators know how to use or create learning objectives. This could lead to pre-clerkship classroom environments without consistent proper use of learning objectives. Without learning objectives, it is difficult to achieve curricular alignment with assessments or maintain consistent emphasis between course content and clinical importance (DaRosa et al., 2011; Ferguson, 1998). This creates an unpredictable learning environment that influences students' self-efficacy, goals and expectations, self-evaluation, and behavior (Bandura, 1989). This influence may manifest as an increase in the likelihood for students to develop feelings of mistrust, uncertainty, frustration, and a decreased sense of agency (Bandura, 1989). It may also lead to students forming inaccurate expectations for assessments, which directly shapes their approach to learning (Bandura, 1989; Collier & Morgan, 2008; Leone et al., 2019; Ramsden, 1991).

The benefits of proper implementation of learning objectives extend to both students and educators. Considering many medical students will be placed in a teaching role with patients, medical students, residents, or a combination thereof during their careers, the incorporation of foundational pedagogical theory into their pre-clinical education is not unreasonable (Dandavino et al., 2007). While the current perceptions and uses of learning objectives by pre-clerkship medical students are not well known, there is literature to describe this for other student populations (Brooks et al., 2014; Duke, 2002; Kuhn & Rundle-Thiele, 2009). Medical residents who were unfamiliar with how to use learning objectives advocated for pedagogical training during their education, demonstrating a willingness to learn the practice (Martin et al., 2016). Similarly, undergraduate biological sciences students reported learning objectives were useful learning aids and that optional training in how to use learning objectives would be beneficial for their academic progression (Brooks et al., 2014).

To determine the best approach to improve the implementation of session level learning objectives by PCBSMEs there is a need to first identify existing opinions and knowledge of learning objectives by PCBSMEs, specifically regarding how they define and use them. Additionally, the degree of communication between PCBSMEs and their students regarding learning objectives needs to be identified to establish any gaps (Alsheikh, 2020; Collier & Morgan, 2008; DaRosa et al., 2011; Leone et al., 2019). The LCME may require program-learning objectives, but the real value in learning objectives overall may be in how the students best utilize them to help guide their learning. If educators are not adequately communicating learning objectives and the importance of their use, then their utility can be called into question whether the curriculum specifically creates them or not. This study sought to investigate existing views of learning objectives held by a sampled group of PCBSMEs by specifically asking educators for their definitions, uses, and experience in creating learning objectives, as well as if and how learning objectives were communicated to pre-clerkship medical students.

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Methods

Study design

This study utilized a phenomenological framework throughout to explore the experiences and opinions of pre-clerkship basic science medical educators (PCBSMEs) regarding learning objectives (Giorgi & Giorgi, 2003). The researchers created a pilot questionnaire to ask PCBSMEs how they defined and utilized learning objectives in medical education. The questionnaire was widely distributed via social media and message boards to PCBSMEs, although responses were low and lacked sufficient detail. The pilot data helped the researchers construct a targeted questionnaire for PCBSMEs which then focused on their use of learning objectives and factors which influenced that use. The questionnaire incorporated a paradigm founded on Bandura's Social Cognitive Theory of Learning (Figure 1) due to emphasis on concepts of observation, modeling, reflection, and modification of goals or perceptions observed in preliminary data from the pilot study (Bandura, 1986; 1989; Schunk, 2020). Questions were designed to focus on the use of learning objectives as tools for themselves and their students, in addition to how the educators communicated the use of learning objectives to their students. The questionnaire consisted of multiple choice, multiple selection, and free response questions (Appendix 1).

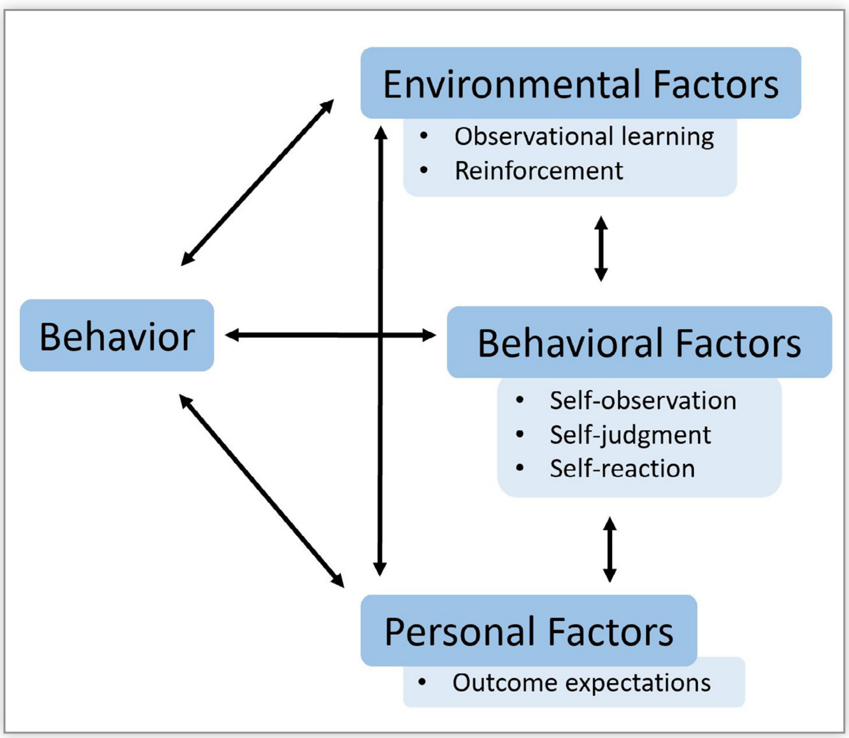

Figure 1. *Visual adaptation of Albert Bandura's Social Cognitive Theory of Learning.*

Setting and participants

Inclusion criteria necessitated the respondents to be currently involved with teaching basic science content to pre-clerkship allopathic medical students. The researchers defined PCBSMEs as individuals who deliver basic science content to pre-clerkship medical students. The basic sciences were defined as those which provide a fundamental understanding of natural phenomena, and which have been further specified by the Association of American Medical Colleges (AAMC; 2024) as "familiar scientific disciplines such as biochemistry, microbiology, physiology, and pharmacology, and their interplay". The questionnaire was distributed to a single allopathic academic medical institution located in the southeastern United States. Completion of the questionnaire was voluntary, self-selected, and participants could withdraw at any point. Participants gave consent by completing the questionnaires.

Data collection

The researchers created a questionnaire based on preliminary results from a pilot study to further investigate PCBSME perceptions of learnings objectives as tools for themselves and their students in addition to communication of learning objectives from PCBSMEs to students. An invitation to complete the questionnaire was disseminated via REDCap (https://projectredcap.org/software/) to all faculty teaching in the basic sciences at the institution of interest (Harris et al., 2009). The questionnaire was sent to institutionally affiliated e-mails in January of 2023. Follow-up reminder e-mails were sent one week and two weeks after the initial invitation.

The questionnaire consisted of multiple choice, multiple selection, and free response questions. Multiple choice and multiple selection questions inquired about demographic information to include level of education and level of medical education at which they were involved with teaching. Free response questions specifically inquired about the respondent's experiences with learning objectives, such as when learning about learning objectives first occurred and through what methods communication about learning objectives takes place.

Data management

The questionnaire was constructed, delivered, and its data stored in REDCap (Harris et al., 2009). No identifiable information was collected from participants. Only the lead researcher (KP) had direct access to the data through a password protected account. Secondary coders (AN and CB) had access to deidentified data through shared permissions from the lead researcher (KP). The lead researcher assigned two-part numeric identifiers to each record wherein the first number

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identified the order of submission of the questionnaire and the second number identified the number of the question for which the response was provided. This study was approved by the Institutional Review Board at the University of Mississippi Medical Center (UMMC-IRB 2022-287).

Data analysis

Free-response questions underwent thematic analysis as described by Kiger and Varpio (2020). Researchers first familiarized themselves with the data before independently generating initial codes. These initial codes were compared between researchers to discuss congruity and differences. Differences in coding were discussed and modified until agreed upon between all researchers before applying the modified codes to the data. Because thematic analysis is a reiterative process, researchers met multiple times to discuss codes until the saturation of data was determined and final codes were agreed upon. Sub-themes and themes were generated independently by the researchers from these final codes and discussed multiple times until agreed upon.

Based on the qualitative nature of this study, the authors acknowledge that each has an inherent bias in the subject matter. Each author has received pedagogical training in the use of learning objectives. The first and second authors were students in an anatomy education doctoral program while the third author has a graduate degree in science education and several years of experience teaching pedagogical theory. However, care was taken to ensure that the data collected from the respondents was analyzed in such a way as to maintain the faithfulness of the given response.

Questionnaire Item	Responses	Response Frequency (%)(n)
1. Did you learn to use learning objectives AS A STUDENT?	Yes	35% (7)
	No	65% (13)
2. Do you utilize learning objectives in your PRE-CLERKSHIP course(s)?	Yes	90% (18)
	No	5% (1)
	Not sure	5% (1)
3. When did you learn to use learning objectives AS A STUDENT?	K-12	0
	Undergraduate College	15% (3)
	Graduate School	15% (3)
	Medical School	5% (1)
	Professional School	0
	Post-Graduate School	0
	Other	0
	Not sure	0
5. Did you learn to use learning objectives AS AN EDUCATOR?	Yes	60% (12)
	No	40% (8)
6. When did you learn to use learning objectives AS AN EDUCATOR?	Undergraduate College	0
	Graduate School	20% (4)
	Medical School	0
	Professional School	0
	Post-Graduate School	5% (1)
	Early Career Faculty (1-5 years)	25% (5)
	Mid-Career Faculty (6-10 years)	10% (2)
	Late-Career Faculty (10 or more years)	0
	Other	0
10. Do you expect your students to know how to use learning objectives prior to being enrolled in your course?	Yes	30% (6)
	No	50% (10)
	Not sure	20% (4)
11. In your experience, how many of your students typically know how to use learning objectives?	All	0
	Most (approximately 75%)	15% (3)
	About Half (approximately 50%)	5% (1)
	Some (approximately 25%)	10% (2)
	A Few (< 25%)	5% (1)
	None	5% (1)
	Not sure	60% (12)

Table 1. *Fixed-item questionnaire items and response frequencies.*

Results

The questionnaire received 28 responses, with 20 retained for analysis. Records were excluded for the following reasons: seven respondents did not complete the questionnaire and one respondent indicated they only taught at the clerkship level. There were seven fixed-item questions which gathered information specific to experience with learning objectives. Some questions were not answered by all participants due to the branching logic of the questionnaire. Most respondents (65%, n = 13) reported they did not learn to use learning objectives as a student with one-third (30%, n = 6) reporting they expected their students to know how to use learning objectives prior to being enrolled in their course. Similarly, 40% (n = 8) of respondents reported they did not learn to use learning objectives as an educator, but the majority reported using learning objectives in their pre-clerkship course(s) (90%, n = 18). Response frequencies to fixed-item questions are reported as percentages in Table 1.

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Free response questions underwent inductive thematic analysis wherein two themes were generated: 1) Educator Experiences and 2) Educator Communications (Figure 2).

Theme 1: Educator experiences

The theme "Educator Experiences" was generated in the context of the respondents reflecting on two different time periods and their experiences with learning objectives during each. This theme was generated from two sub-themes based on the two different time periods: 1) Use as Student and 2) Methods of Learning to Use Learning Objectives Once in an Educator Role.

Sub-theme 1A: Use as a student

Sub-theme "Use as Student" was generated to organize responses describing the time or environment in which first encounters with learning objectives occurred. An example is illustrated by Record ID 17-08 stating, "when given syllabus in undergraduate courses."

This sub-theme also included responses which described ways these respondents were taught to utilize learning objectives while they were a student. Responses were varied but largely included descriptions of learning to use learning objectives as a tool to aid their own learning. Several responses which illustrated the specific actions they took with learning objectives are listed below:

- "As a guide to studying for exams." (Record ID 24-08)
- "Learning objectives served as a guide as to what concepts were important in lectures and also focused my preparation for exams" (Record ID 1-08)
- "I learned to use objectives as a way to provide a checklist of what are the most important aspects of a lecture. I learned that this should help form a non-exclusive outline for understanding the material. Non-exclusive meaning just because a topic may not be on the objectives list, it does not mean it might not be important." (Record ID 5-08)

Sub-theme 1B: Methods of learning to use learning objectives in an educator role

This sub-theme was generated to describe various ways by which the skills of utilizing learning objectives as an educator were learned. Responses ranged from describing formal training to self-teaching as indicated by Record ID 21-11 stating, "reading professional journal articles, attending annual conference meetings, teaching course [sic] with other faculty members and understanding what students need to learn." Several respondents also indicated learning from their colleagues as described below:

- "I learned to use learning objectives from my colleagues" (Record ID 1-11)
- "By example from established teachers." (Record ID 4-11)
- "Experienced faculty was also very helpful and previous lectures to determine flow of the lectures." (Record ID 12-11)

Respondents also described how they were taught to use learning objectives as tools to aid in the practice of backwards design (Bowen, 2017) when creating curricular content. One respondent expressed this by stating:

- "I took coursework in teaching and in doing so was introduced to the use of objectives to guide a class session as well as a course. Among the ways we were taught was in using backwards design to ensure that the objectives for the course were measured through assessment as well as covered in a class session." (Record ID 7-11)

Theme 2: Educatory Communications

The theme "Educator Communications" described how PCBSMEs communicate to their students about learning objectives. This theme was generated from two sub-themes: 1) General Communications and 2) Use-Specific Communications.

Sub-theme 2A: General Communications

This sub-theme described how actively these PCBSMEs communicate to their students about learning objectives. Responses ranged from describing no communication, inconsistent communication, or consistent communication. No communication includes responses where the communication specific to learning objectives was described as absent or minimal such as acknowledging the existence or location of their learning objectives but nothing more. Two examples are provided below:

- "I don't, [students] are just given the word document with the objectives." (Record ID 17-12)
- "I just put them on the lab instructions and email." (Record ID 3-12)

Some responses describing no communication identified specific obstacles which prevented communication regarding learning objectives.

- "... insufficient time is allotted to cover course material, so there is definitely insufficient time to go over the objectives themselves in any detail." (Record ID 2-12)

Inconsistent communication includes responses wherein communication regarding learning objectives differed depending on subject or learning environment.

- "I include the learning objectives as the first slide of each PowerPoint presentation for each lecture…I also include a written description for small group sessions and verbally emphasize the main objectives." (Record ID 13-12)

Consistent communication includes responses describing a routine communication about learning objectives and an active practice of directing students toward using them.

- "I introduce objectives on the first day of class as the best source of information, and the answer to 'what do we need to know'. I make sure to point them out and review them every class session, and I encourage students to base their study around these objectives." (Record ID 7-12)

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Sub-theme 2B: Use-specific communications

Sub-theme "Use-Specific Communications" described communications from these PCBSMEs to students about specific ways to use learning objectives. Responses indicating this specific communication does occur described suggestions for students to use learning objectives as tools. More specifically, these recommendations described using learning objectives to prepare for assessments by focusing content and practicing metacognitive habits. Various recommendations are described by the following statements:

- "I suggest they look at them before class and after class when they review the material." (Record ID 13-13)
- "I encourage them to start their study with an open ended [sic] recall of the objectives." (Record ID 7-13)
- "I tell them that the best way that I know how to use the topic lists is to study until they are able to explain, verbally or in writing, any item on the topic list WITHOUT [sic] needing to consult notes, slides or textbooks. Once the student has that capability, they have mastered that topic item, at least in the time frame of the next exam!" (Record ID 25-13)

Responses also included how this specific communication does not occur. The following quotes represent this lack of communication:

- "Little or no time is spent by me discussing ways to use learning objectives." (Record ID 2-13)
- "I do not specifically tell the students how to use the learning objectives." (Record ID 19-13)

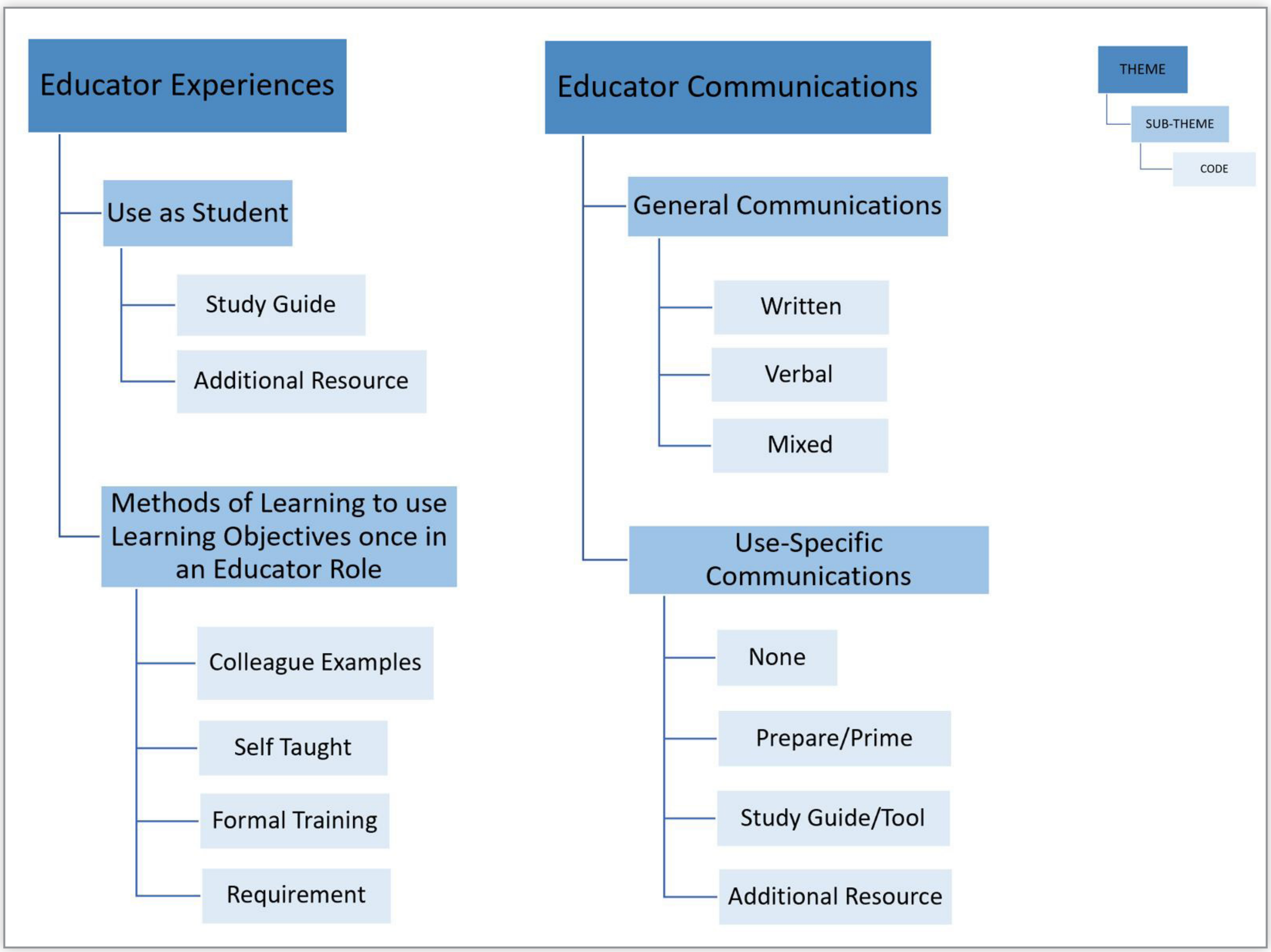

Figure 2. *Inductive thematic analysis results of qualitative data.*

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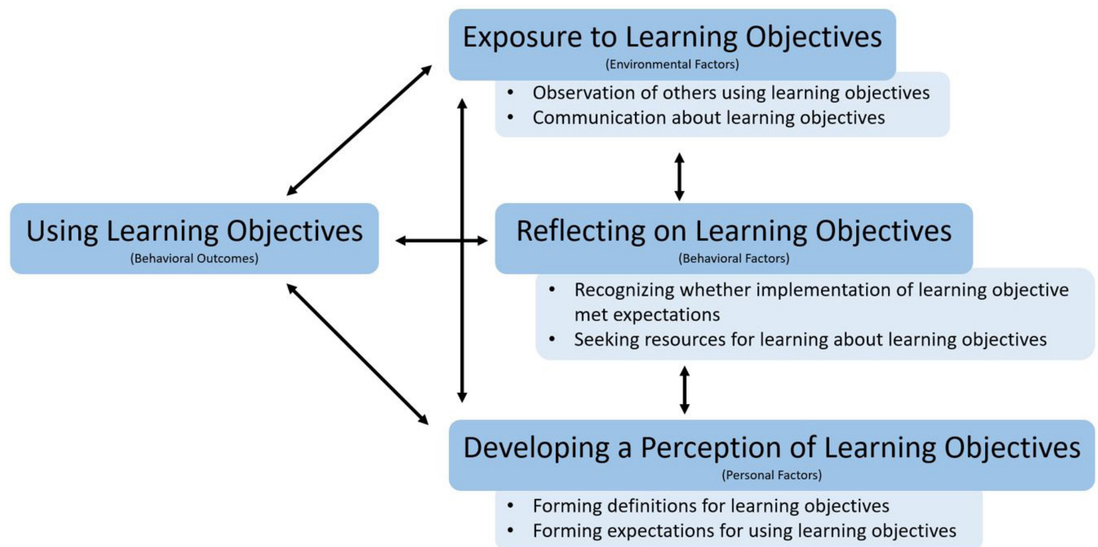
Discussion

This study was designed to investigate how PCBSMEs learned about learning objectives and subsequently how they currently utilize them. This study also investigated communications regarding learning objectives from PCBSMEs to their students. The two themes were generated from codes which reflect the different factors of Bandura's Social Cognitive Theory of Learning (Figure 2). This can be appreciated in that these PCBSMEs stated they learned about learning objectives by observing and receiving communication from others, forming expectations, and reflecting and modifying their framework regarding learning objectives as they gained more experience in their faculty role (Bandura, 1989; Ramsden, 1991). Based on the presented results, Figure 3 was developed to hypothesize the interrelationship between the different experiences educators may have regarding learning objectives and their use of said learning objectives. After modifying the framework to fit the context of learning objectives, each factor (environmental, behavioral, and personal) can be appreciated by the resulting themes and corresponding exemplar quotes from the data.



SCT Model Element	Theme (Code)	Quote
Environmental Factor	Educator Experiences (Colleague Examples)	"**By example** from established teachers." (ID 4)
Environmental Factor	Educator Experiences (Tool)	"**Among the ways we were taught was in using backwards design** to ensure that the objectives for the course were measured through assessment as well as covered in a class session." (ID 7)
Environmental Factor	Educator Experiences (Formal Training)	"**I took coursework in teaching** and in doing so was introduced to the use of objectives…" (ID 7)
Behavioral Factor	Educator Experiences (Tool)	"Early in my **career I found myself still trying to stay ahead** of the students with regard to content knowledge. Using learning objectives that others had prepared **helped me focus my own learning** to prepare for class. **Writing my own learning objectives was also a helpful activity,** as I had to really refresh content and think about what the students needed to know. **It helped to focus my own efforts as an educator** as I prepared for class." (ID 12)
Behavioral Outcome	Educator Communications (Active)	"**I inform the students that I utilize the topic lists as I write my exam questions**. Every question must be directly related to one or more items on the topic lists. There are no exceptions." (ID 25)
Personal Factor	Educator Communications (Additional Resource)	"We tell them that the **learning objectives do not include all information required** to do well in the course." (ID 4)

Figure 3. *Schematic for Albert Bandura's Social Cognitive Theory of Learning (top) and as it hypothetically applies to learning and using learning objectives for participants of this study (bottom).*

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The first theme, Educator Experiences, describes how these PCBSMEs became familiar with learning objectives during their time as a student and as an educator and can serve as the environmental factor within the proposed model. The experiences of Theme 1 provide material for the individual to reflect upon and form expectations, which serve as behavioral and personal factors, respectively, within the model. For these educators, there is likely a relationship between these two time periods in that if the respondent indicated exposure to learning objectives as a student, then they probably formed a perceived value of learning objectives at this time. This perceived value may be reflected in a behavioral outcome of whether, and specifically how, the respondent utilizes learning objectives as an educator. Further investigation is necessary to quantify the strength of this relationship.

Similarly, these experiences may influence a different behavioral outcome which Theme 2, Educator Communications, describes. If the respondent did not learn about the value of using learning objectives, then it is possible they are less likely to actively communicate about learning objectives to their students. In contrast, if the respondent learned about the value of learning objectives, it may be more likely they will actively communicate about learning objectives to their students. To help illustrate this hypothesis, two respondents who self-reported different environmental factors also described different personal factors and behavioral outcomes (Table 2). Record ID 2 responded "No" to learning to use learning objectives as an educator whereas Record ID 7 responded "Yes". Record ID 2 then described passive communication to their students about learning objectives and no communication to their students regarding specific ways to use them. In contrast, Record ID 7 described active communication to their students regarding learning objectives and use-specific communication in the form of a recommended way to use them to support their learning. While this is one example, it provides evidence to support future analyses which could quantify the relationship between these factors.

Questionnaire item	Record ID 2	Record ID 7
Did you learn to use learning objectives AS A STUDENT?	No	No
Did you learn to use learning objectives AS AN EDUCATOR?	No	Yes
When did you learn to use learning objectives AS AN EDUCATOR?	*No response due to branching logic of questionnaire*	Graduate School
How did you learn to use learning objectives AS AN EDUCATOR?	*No response due to branching logic of questionnaire*	"I took coursework in teaching and in doing so was introduced to the use of objectives to guide a class session as well as a course. Among the ways we were taught was in using backwards design to ensure that the objectives for the course were measured through assessment as well as covered in a class session."
How do you COMMUNICATE to your students about your learning objectives?	"Learning objectives are included in the syllabus, in online materials (e.g. course canvas site), and are listed at the beginning of lectures (and included in the powerpoint which is also provided to students)."	"I introduce objectives on the first day of class as the best source of information, and the answer to "what do we need to know". I make sure to point them out and review them every class session, and I encourage students to base their study around these objectives. On the other side, I also make sure that my exam questions are grounded in the objectives that were selected for the class as a whole and the sessions from that block or unit to ensure that I am testing what was deemed most important for the course."
How do you tell your students to USE your learning objectives?	"Little or no time is spent by me discussing ways to use learning objectives. First, they should be largely self-explanatory. Second, insufficient time is allotted to cover course material, so there is definitely insufficient time to go over the objectives themselves in any detail."	"I encourage them to start their study with an open ended recall of the objectives. I also remind them, daily if necessary, that they don't need to ask what is important because it is outlined in the objectives."
Do you expect your students to know how to use learning objectives prior to being enrolled in your course?	Yes	No

Table 2. *Questionnaire data from selected records (Record ID 2 and 7) which illustrate a difference in behavioral outcomes.*

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Theme 2 - Educator Communications also revealed there may be obstacles in place which prevent proper implementation and communication regarding learning objectives for these educators. One obstacle may be a lack of training as indicated by some respondents. Several stated they did not learn to use learning objectives as an educator until they were in a faculty position. This is likely because most PCBSMEs do not have formal training in pedagogy, as it is not a requirement to secure a faculty position within medical academia (Association of American Medical Colleges, 2022). This lack of training may exacerbate an already inherent amount of variation with approaches to pre-clerkship teaching in addition to problems that arise when learning objectives are not used or used improperly (Alsheikh, 2020; Bandura, 1989; Collier & Morgan, 2008; Leone et al., 2019).

Another obstacle may be the challenge of limited time provided to cover a large volume of information. Some of these PCBSMEs indicated that it is more important to use class time to expose students to all the session content and leave navigation of the learning objectives for them to do on their own. Further investigation is necessary to identify the breadth of these obstacles and whether action can be taken to mitigate them.

Because of this, providing early exposure to pedagogical concepts, including learning objectives, may be beneficial to several stakeholders within medical education. This exposure could be presented in several ways. One option is a mandatory course or workshop in basic science doctoral programs which focuses on foundational pedagogical concepts and practices. Another option is to include a training session which covers similar concepts as part of new faculty onboarding for positions with teaching responsibilities. Both suggestions use a proactive approach to address the lack of pedagogical training for potential PCBSMEs, rather than a reactive approach once the individual is teaching.

Limitations

The authors acknowledge several limitations to this study. First, the nature of the questionnaire made thorough collection of the thoughts and opinions about learning objectives limited. Respondents most likely would expand on these given additional data collection methods such as structured interviews. Also, this study was conducted at a single institution, and different institutions place different levels of emphasis on using current pedagogical methods. Additionally, a variety of educators responded, and it is unknown what level of involvement each of these educators had in program or course level curricular development. Lastly, while the study aimed to explore perceptions regarding session-level learning objectives the questionnaire did not explicitly state this. Therefore, respondents may have completed the questionnaire with regard to other level learning objectives in mind. Future studies should evaluate involvement to assist in providing more context to the responses. The sample size was not large enough to investigate correlations between non-qualitative data, but additional data collection could reveal such relationships exist.

Future directions

Based on this study, the researchers suggest further investigation into how PCBSMEs acquire knowledge regarding learning objectives. This may include surveying resource availability or obstacles preventing access, redirecting current resources, or the development of novel resources. Additionally, gathering the perspectives of other stakeholders, such as medical students or department chairs, regarding value of learning objectives and perceptions on PCBSME communication would improve understanding of how effective learning objectives are for students and identify potential areas of improvement. Capturing the perspectives of stakeholders at higher levels, such as the LCME, may more easily facilitate appropriate changes with a top-down approach. Finally, the framework presented could lead to quantitative research that explores the strength of different factors into the use and the effectiveness of learning objectives in medical education. Creating a standardized assessment of learning objective use could provide necessary relationships and align best practices for all involved in medical education.

Conclusion

This study broadly suggests the learning experiences of a student may influence their approach to teaching. More specifically, a limited experience and understanding of learning objectives may limit how effectively a PCBSME implements and communicates learning objectives to their students. Further investigation is necessary to acquire more generalizable results describing PCBSME understanding and implementation of learning objectives. This data can be used to develop strategies for improved implementation of learning objectives and encourage practice of empirically supported pedagogy within basic science courses of medical education. Additionally, gathering perspectives of learning objectives from other stakeholders within medical education such as curriculum designers, students, and administrators would provide a more complete understanding of how best to train educators in implementation and communication.

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About the Authors

Kayla Pavlick is a graduate student in an anatomical sciences education track program at the University of Mississippi Medical Center and, as primary researcher, was responsible for the conceptualization, methodology, data collection and analysis, and writing of the manuscript in partial fulfillment of their dissertation. Casey Boothe is an Assistant Professor at the University of Mississippi Medical Center but was a graduate student in an anatomical sciences education track program at the University of Mississippi Medical Center at the time of analysis for this study. She was involved with the methodology, data analysis, and manuscript editing. Andrew Notebaert is an Associate Professor and Program Director at Northern Illinois University and participated in the conceptualization, methodology, data analysis, and manuscript editing.

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Appendix 1. Questionnaire distributed to pre-clerkship basic science medical educators in January of 2023

Demographics

1. Please indicate your age range:
   a. 20 – 30
   b. 31 – 40
   c. 41 – 50
   d. 51 – 60
   e. 60 or older

2. Please indicate your race:
   a. African American
   b. Asian
   c. Caucasian
   d. Hispanic
   e. Other
   f. Prefer not to say

3. Please indicate at what level(s) you teach medical students:
   a. Pre-clerkship ONLY
   b. Clerkship ONLY
   c. Both pre-clerkship and clerkship
   d. I do not teach medical students

4. Please indicate your highest level of education achieved:
   a. Bachelor's Degree
   b. Master's Degree
   c. PhD
   d. MD or DO
   e. Other
      i. Please specify: ___________________________________

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Learning Objectives

1. Did you learn to use learning objectives AS A STUDENT?
   a. Yes
   b. No

2. Do you utilize learning objectives in your PRE-CLERKSHIP course(s)?
   a. Yes
   b. No
   c. Not sure

3. When did you learn to use learning objectives AS A STUDENT?
   a. K-12
   b. Undergraduate College
   c. Graduate School
   d. Medical School
   e. Professional School
   f. Post-Graduate School
   g. Other
   h. Not sure
      i. Please specify: ___________________________________

4. How did you learn to use learning objectives AS A STUDENT? Please include as many details as possible.

____
____

5. Did you learn to use learning objectives AS AN EDUCATOR?
   a. Yes
   b. No

6. When did you learn to use learning objectives AS AN EDUCATOR?
   a. Undergraduate College
   b. Graduate School
   c. Medical School
   d. Professional School
   e. Post-Graduate School
   f. Early Career Faculty (1-5 years)
   g. Mid-Career Faculty (6-10 years)
   h. Late-Career Faculty (10 or more years)
   i. Other
      i. Please specify: ____________________________________

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7. How did you learn to use learning objectives AS AN EDUCATOR? Please include as many details as possible.

____

8. How do you COMMUNICATE to your students about your learning objectives? Please include as many details as possible.

____

9. How do you tell students to USE your learning objectives? Please include as many details as possible.

____

10. Do you expect your students to know how to use learning objectives prior to being enrolled in your course?

a. Yes
b. No
c. Not sure

11. In your experiences, how many of your students typically know how to use learning objectives?

a. All
b. Most (approximately 75%)
c. About Half (approximately 50%)
d. Some (approximately 25%)
e. A Few (< 25%)
f. None
g. Not sure

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How Does Utilizing Clicker Questions for Exam Preparation Affect Test-Taking Anxiety in Human Anatomy Students in a Flipped Classroom?

Dalia Salloum, PhD[1], Kamie Stack, ABD[2], Suzanne Hood, PhD[3]

[1]Salt Lake Community College, Taylorsville, UT, USA
[2]University of Minnesota, Minneapolis, MN, USA
[3]Bishop's University, Sherbrooke, QC, Canada

Corresponding author: dalia.salloum@slcc.edu

Abstract

While active learning strategies have been promoted by researchers as practices to increase performance and retention, some practices have been shown to have unintended negative effects on students such as increasing anxiety. Students often report the debilitating effect of test-taking anxiety on their performance. This study investigated the use of an exam preparation process utilizing clicker questions to help human anatomy students at a community college cope with test-taking anxiety by practicing answering timed questions and regularly confronting the specific impact of anxiety on their performance. Students completed early and late semester surveys which measured self-reported test-taking anxiety levels and social anxiety in response to various teaching practices. There was no difference in test-taking anxiety between students who received clicker questions and students who did not. However, when comparing test taking anxiety across a subset of students who took both the early and late surveys, independent of treatment, a significant decrease in test taking anxiety was observed from the start to the end of the semester. Students also reported a change in effectiveness of teaching practices, rating lectures as effective early in the semester, while emphasizing active learning more at the end of the semester. https://doi.org/10.21692/haps.2024.005

Key words: active learning, flipped classroom, test-taking anxiety, coping skills, clickers

Introduction

Active Learning

The traditional lecture-based approach in college classrooms is slowly being recognized as an inefficient and ineffective way to create meaningful learning experiences. This is not to say that lecturing is not a reliable way to transfer information; but with the technology available, it can be done through video streaming and recordings outside of the classroom. Active learning is a more effective strategy to increase student success in college classrooms across institutions and disciplines (Entezari & Javdan, 2016; Freeman et al., 2014; Jensen et al., 2015). In anatomy and physiology courses, students struggle with the sheer volume and difficulty of concepts presented. Students struggle to succeed and some of them must repeat the courses to achieve grades that allow them to move forward in their prospective health programs. This is especially true of marginalized and first-generation students who have the added barrier of access and knowing how to navigate the invisible curriculum. Active learning and increased course structure are major components of an inclusive teaching environment as defined by Kelly Hogan and Viji Sathy (2022). Increasing course structure creates more opportunities for students to assess their knowledge with frequent, low-stakes assessments rather than a few high stakes assessments as in a traditional STEM college course.

The Flipped Classroom

In a flipped classroom, students spend very little time in the classroom listening to an instructor deliver a lecture. Rather, the lecture is delivered outside the classroom using video recordings. Activities conventionally done at home, such as quizzes, worksheets, and open-ended questions are done in the classroom under the guidance of the instructor. The flipped classroom has been shown to be effective in increasing student performance in anatomy and physiology courses (Entezari & Javdan, 2016; Tune et al., 2013), as well as across various disciplines in higher education (Deslauriers & Wieman, 2011). It also lends itself well to a regular practice of active learning.

It has been shown that the successes in the flipped classroom are attributed specifically to active learning strategies that allow students to be engaged with their peers and instructors, reflect on their own thinking processes, and

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deconstruct difficult concepts in the classroom (Jensen et al., 2015). Students are exposed to and acquire a habit of regularly learning through evidence-based instructional practices such as think-pair-share, muddiest points, collaborative quizzes, drawing to learn, and clicker questions. Students from historically excluded and marginalized groups can greatly benefit from a teaching approach that scaffolds a path to mastery of core concepts using classroom time to reinforce concepts and study skills (Nardo et al., 2022; White et al., 2021).

Clicker Questions

One such active learning strategy that this research will focus on is the use of an online quizzing system with live clicker questions which allows students to use their smartphones, laptops, or tablets as the response device to timed questions displayed on the projector. A histogram with correct versus incorrect responses is displayed on the screen after the timer ends and the instructor can directly address misconceptions. The students can use anonymous nicknames and, for the purposes of this study, the questions did not count towards the students' final grades.

The use of clickers allows students to respond to various types of questions including multiple choice questions (MCQs), true/false (T/F), open-ended, and labeling images or figures in real time while displaying the percentage of correct versus incorrect responses. It allows the instructor to observe the extent to which a particular concept requires attention based on the results of the clicker question displayed after each question. This technology promotes student-centered learning in the classroom and serves as an opportunity for the instructor to address approaches to exam-style questions, test-taking anxiety, and reading comprehension.

Classroom practices that increase student engagement such as clickers, worksheets, cooperative learning, think-pair-share, and others have been shown to increase student success across undergraduate STEM courses when compared to a purely lecture-based course (Freeman et al., 2014). Many studies have demonstrated the successes of these practices in STEM classrooms but few have considered that some practices might have negative effects such as increasing anxiety (England et al., 2017). Some instructional practices, especially those with a social component, have been shown to provoke anxiety in college students, and more so in first-generation college students (Hood et al., 2020, 2021). The use of clickers in the classroom are rated by students to provoke lower levels of anxiety, levels that are comparable to passively listening to an instructor give a lecture. In contrast, practices like cold-calling provoke higher levels of anxiety and first-generation students consistently rate all these practices as more anxiety promoting compared to their continuing-generation peers.

Academic Anxiety

When discussing anxiety provoking instructional practices, we're referring to state anxiety as opposed to trait anxiety. State anxiety is a feeling or emotional state, typically situational, while trait anxiety is a characteristic of the person (Endler & Kocovski, 2001). Anxiety is reported in college students and more so in science classes. It can have negative effects on exam performance if not resolved (Okebukola, 1986).

Even though some practices provoke anxiety in students and more so for particular groups of students, it is important to address the reasons why students may be undergoing this psychological stress and teach them how to cope with it rather than avoiding using these techniques. Clicker systems were rated as causing lower levels of anxiety by students surveyed when compared to other practices such as cold-calling, volunteering to answer a question, or completing worksheets (England et al., 2017; Hood et al., 2020). Students at SLCC frequently report exams as inducing high levels of anxiety, test-taking anxiety, and negatively affect their performance despite feeling prepared and comfortable with the material. This study aimed to use timed, exam-style clicker questions to help students cope with test-taking anxiety. The hypothesis was that by practicing timed questions with the instructor and continuously confronting the specific impact of anxiety on their performance, students would report lower levels of anxiety and higher levels of academic self-efficacy or their perceptions about their own academic abilities.

The research project investigated the following questions:

1. *How does using clicker questions affect test-taking anxiety in human anatomy students in a flipped classroom?*
2. *How do various evidence-based instructional practices (EBIPs) affect students' self-reported anxiety levels?*
3. *How do students perceive effectiveness of various EBIPs?*

Methods

Study Design

This study was conducted in the Fall 2022 semester following Institutional Review Board approval and student consent. The participants were enrolled in a one semester Human Anatomy course that is a prerequisite for all students going into health science programs (nursing, radiology technician, dental hygiene, etc.) and typically taken during the second year of an associate degree.

The study was conducted using two course sections taught in a *hybrid modality,* meaning students registered for a 3-credit hour course which met synchronously once per week for 80-minute sessions. Students were expected to engage with course material asynchronously online through

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the Learning Management System (LMS) to account for the remaining credit hours. Both sections were taught as *flipped classrooms* where students were required to watch all lecture content at home through prerecorded videos and perform various learning activities, quizzes, group work, and assignments in the classroom during synchronous class meetings under the supervision of the instructor. One section was designated as the control group and the other section was designated as the intervention group (clicker group).

Student Survey

Students responded to a set of survey questions at the beginning (early) and end (late) of term. This meso-level survey contained three instruments that measured students' self-reported academic self-efficacy, social anxiety (mini-SPIN; Connor et al, 2001), and test anxiety (Spielberger Test Anxiety Inventory, Spielberger et al., 2014). Students responded to various statements in each instrument by rating their level of agreement or disagreement on a Likert scale. The social anxiety section had 5 questions to measure students' self-perception of their anxiety related to EBIPs, and 5 questions about how those EBIPs contributed to their learning. The test-anxiety section asked them to report how often they felt various emotions related to nervousness and discomfort around taking exams. The academic self-efficacy section asked 10 questions about students' beliefs in their abilities.

The social anxiety and academic self-efficacy measurements were part of a larger study for the CAPER project and therefore are not discussed in detail here. This study focuses on the effects of clicker questions on test-taking anxiety. Students were additionally given the Test Anxiety Inventory (TAI) before each exam (before exam 2, 3, and 4). Students were given a review session before each lecture exam and then completed the TAI. Students responded to the TAI a total of 5 times throughout the semester: timepoint 1 was during the first two weeks of the term, timepoint 2 was during week 5 before unit exam one, timepoint 3 was during week 9 before unit exam two, timepoint 4 was during week 13 before unit exam 3, and timepoint 5 was during week 17 before unit exam four and the final examination. Students did not receive an exam preparation session before the 3rd unit exam because the instructor had COVID and was not able to administer that session.

The group who received the intervention (clicker group) participated in an exam preparation session with a timed online quiz using clickers while the control group was given a similar exam preparation session but without the use of clickers and timed questions. Instead, the instructor projected learning objectives and various questions to help students discuss which concepts they wanted the instructor to clarify. The clicker group's exam preparation session aimed to simulate the testing environment by timed, exam style clicker questions. The questions were either multiple choice or true/false and tested on concepts that would be covered in the unit exam that followed.

Question Prompt to Students	Answer Choices
Which structure is derived from the peritoneum of the abdominal cavity?	A. mediastinum testis B. tunica vaginalis C. raphe D. spermatic cord
Which is not a function of the urinary system?	A. regulation of lymphocyte production B. storage of urine C. regulation of blood volume D. excretion of wastes
The capillaries of the glomerulus differ from other capillary networks in the body because they:	A. drain into an arteriole instead of a venule B. filter nutrients from the glomerular capsule C. absorb nutrients from the glomerular capsule D. secrete mucus
Which gland secretes a fluid containing fructose?	A. seminal vesicle B. erectile bodies C. vestibular gland D. prostate gland

Table 1. *Examples of questions and learning outcomes projected for clicker group preparation session (taken from power point slides in the review sessions).*

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Task/Question	How students demonstrated their understanding of the learning target
4.9 Identify where each type of connective tissue is found in the body.	Students discuss in groups
4.11 Explain the structure and function of skeletal, cardiac, and smooth muscle.	4.11 Which of the following muscle types is **voluntary**? A. skeletal B. cardiac C. smooth
1.2 Describe the hierarchical levels of organization in the human body.	1.2 Which of these places the organization of structures from most complex to least complex? A. organism, tissue, cell, organ, organelle B. organelle, cell, tissue, organ, organ system C. organ system, organ, tissue, cell, organelle
4.4 Explain where each epithelial tissue is found in the body.	Students discuss in groups

Table 2. *Examples of questions and learning outcomes projected for control group exam preparation session.*

Preparation sessions for both the clicker and control groups took 20-30 minutes during the class meeting and included 15-25 questions. Questions were displayed on the projector with a timer of about one minute per question for the clicker group whereas the control group did not have a timer and students were not required to respond in a definitive way other than discussing possible answers with their peers.

Student Population

Students enrolled in the human anatomy course, BIOL2320, at Salt Lake Community College (SLCC) are predominantly 2nd year pre-health majors going on to professional programs or transferring to four-year institutions for various health science career-related programs. SLCC serves a large population of Hispanic and Latino/a/x students, first generation, and non-traditional students.

Identified Gender, % (n)	
Male	5.6 (4)
Female	58.3 (42)
Ethnicity, % (n)	
White	47.2 (34)
Black	5.6 (4)
Native or Alaskan Native	1.4 (1)
Asian	5.6 (4)
Other	4.2 (3)
Missing	33.3 (24)
Latino/a/x Origin, % (n)	
No	48.6 (35)
Yes	16.7 (12)
Missing	34.7 (25)
First Generation Status, % (n)	
No	45.8 (33)
Yes	20.8 (15)
Missing	33.3 (24)

Table 3. *Demographic data of student participants. Students self-identified their gender, ethnicity, Latine origin, and first-generation status (n = 72). One student responded non-binary and one responded gender queer and non-binary. One student responded prefer not to say for ethnicity.*

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Test-Taking Coping Skills for All Student Participants

All student participants in this study were introduced to the relationship between stress and performance (Chaby et al., 2015) as well as the effect of deep diaphragmatic breathing on heart rate (Magnon et al., 2021). Throughout the semester, student participants were reminded regularly by the instructor of the value of mindfulness as a coping mechanism for testing anxiety. Prior to the first exam, the instructor led the class in a mindful meditation to guide students in visualizing themselves in a testing environment, focusing on breathing, and persisting through feelings of discomfort. During review sessions before each exam, students were again reminded to lean on these skills to aid in alleviating the debilitating effects of test anxiety.

Data Analysis

Survey. All quantitative results from responses on the Likert scale were downloaded to Microsoft Excel for manipulation. Results were from 5 different time points (1st through 5th). The measures of social anxiety, test-taking anxiety, and open-ended questions about effectiveness of various EBIPs were administered during the first timepoint (week 1-2) and 5th timepoint (week 15-16).

Test Anxiety Inventory. TAI reported values were collected using Qualtrics survey instruments on a Likert scale. Mean TAI ratings were compared across time points between the control group and the clicker group to test the hypothesis that timed clicker questions would help alleviate test-taking anxiety.

To measure what happened with test anxiety for all students who completed the 1st and 5th semester surveys, we compiled the reported values and did a paired sample students t-test with a Wilcoxon post hoc test.

Social Anxiety in Response to EBIPS: Results from the social anxiety instrument were compiled and downloaded. We looked at social anxiety self-reported values in response to various EBIPs from the 1st and 5th timepoints.

Qualitative Results. At the end of the social anxiety inventory, students were asked "For the activities that you found helpful, please explain why they were helpful. Did they help you develop more effective study strategies? If so, what were those strategies?"

The first step in the analysis was to read through all the open responses and identify recurring themes in each of the 1st and the 5th timepoints. These themes were coded by listing them in a table. Next, we tallied how many times each of the themes appeared and compiled them into tables. Once finalized, representative quotes were selected from each theme.

Results

Quantitative Results

No difference in the mean Test Anxiety Inventory (TAI) between the control and clicker groups was observed across time points (Figure 1, Table 4, and Table 5). However, when data was compiled to compare TAI ratings for only participants who completed the 1st and 5th semester survey, a paired sample t-test showed a significant decrease from the beginning of the semester to the end of the semester independent of whether or not students were exposed to clicker questions in their pre-exam preparation (Figure 2). The mean TAI rating at the 1st timepoint was 56.0 and it decreased to 41.7 in the 5th timepoint ratings.

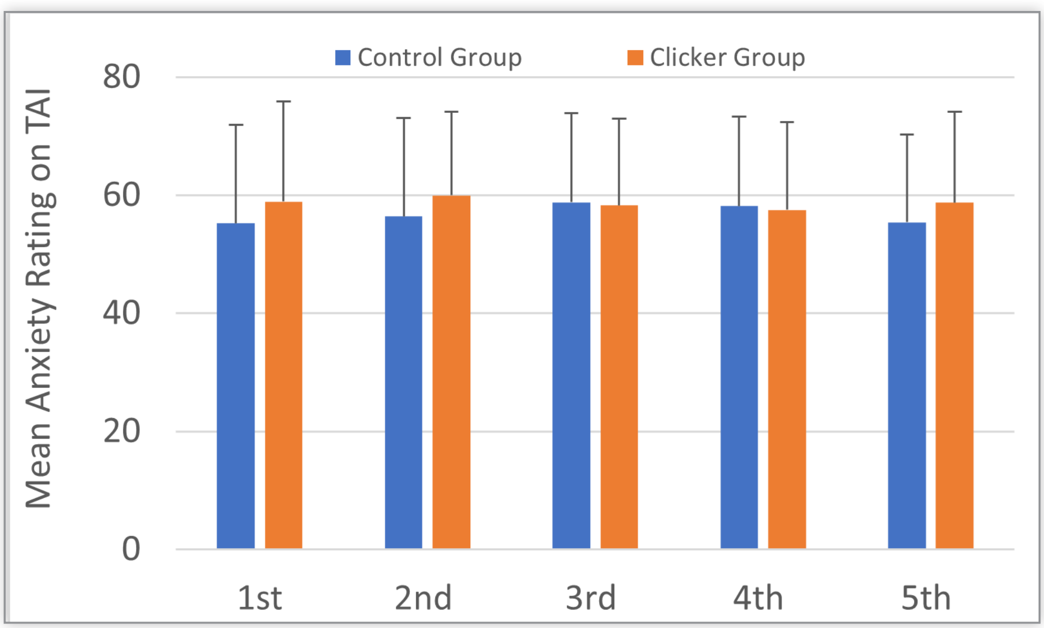

Figure 1. *Mean test anxiety inventory ratings between control and clicker groups. Students took the Spielberger's TAI 5 times throughout the semester. 1st timepoint (control group, n=24; clicker group, n= 21), 2nd timepoint (control group, n=20; clicker group n=23), 3rd timepoint (control group, n=25; clicker group, n=24), 4th timepoint (control group, n=15; clicker group, n=23), 5th timepoint (control group, n=18; clicker group, n=28).*

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	TAI Rating 1st Timepoint	TAI Rating 2nd Timepoint	TAI Rating 3rd Timepoint	TAI Rating 4th Timepoint	TAI Rating 5th Timepoint
N	24	20	25	15	18
Mean	55.3	56.4	58.8	58.1	55.4
Std. Deviation	16.7	16.7	15.1	15.2	14.9

Table 4. *Control group mean TAI scores over time.*

	TAI Rating 1st Timepoint	TAI Rating 2nd Timepoint	TAI Rating 3rd Timepoint	TAI Rating 4th Timepoint	TAI Rating 5th Timepoint
N	21	23	24	23	28
Mean	58.9	60.0	58.2	57.5	58.8
Std. Deviation	17.0	14.2	14.7	14.8	**15.3**

Table 5. *Clicker group mean TAI scores over time.*

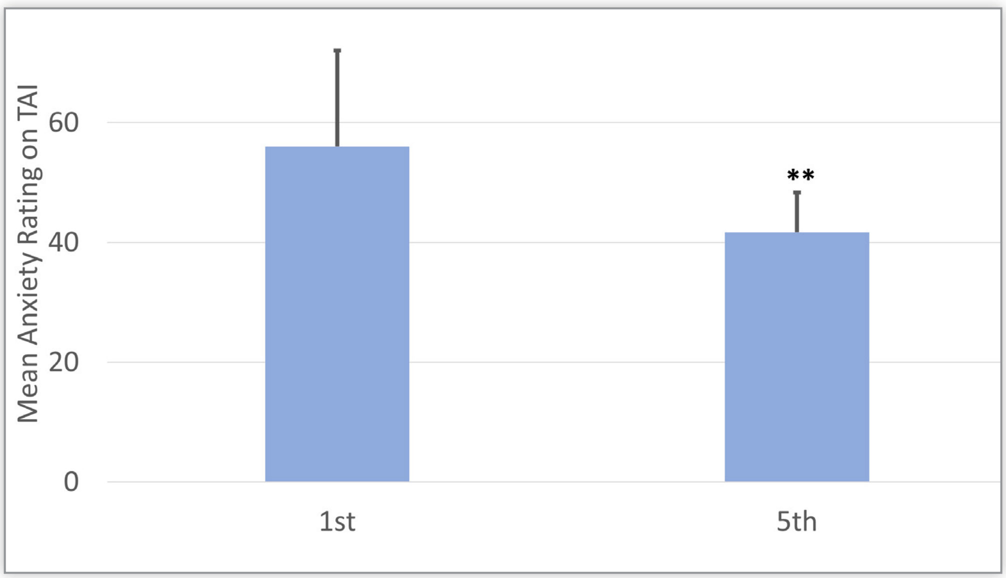

Figure 2. *Compiled anxiety ratings on TAI for students who completed 1st and 5th timepoint surveys (n=35).*

We next analyzed student ratings of anxiety caused by various teaching practices. Examination of the data revealed that the distributions of these ratings did not meet the assumption of normality, so non-parametric inferential tests were used to test for differences. Figure 3 shows the mean anxiety ratings of five different teaching practices that student reported at the start of term (1st timepoint) and end of term (5th timepoint). No significant differences were found in these ratings between the control and clicker groups, so data from the two groups were pooled. Comparison of ratings using a Friedman test indicated significant differences across the five teaching practices (χ^2 (4) = 97.2, $p < 0.001$). Follow-up pairwise comparisons using the Durbin-Conover test indicated significant differences between all practices except for between the use of clickers alone and with others, which did not differ significantly in rated anxiety (see supplementary materials for these test statistics). As shown in Figure 3, cold calling received the highest anxiety rating whereas lecturing with PowerPoint received the lowest.

We next analyzed ratings made at the end of the term, which are shown in Figure 3. At this time point, students were also asked to rate the use of the clicker app for induced anxiety. The results of a Friedman test indicated significant differences in ratings across these six teaching practices (χ^2 (5) = 131, $p < 0.001$), and post-hoc comparisons revealed

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differences between all practices. Similar to ratings made at the start of term, anxiety ratings at the end of term were highest for cold calling and lowest for lecturing.

Additional pairwise comparisons of ratings made at the 1st and the 5th timepoints were conducted for each practice. These comparisons indicated no statistically significant differences in ratings over time for each of the five teaching practices.

Qualitative Results

Early Semester Survey

Recurring themes identified in student responses to the question, "For the activities that you found helpful, please explain why they were helpful. Did they help you develop more effective study strategies? If so, what were those strategies?"

Most students mentioned at least one of the five themes (Table 3) that corresponded to the five EBIPs mentioned in the previous questions. In the beginning of the semester, students focused on listening to lecture videos or going through PowerPoint presentations while listening to the instructor. This was the most common response; it appeared 18 times in the early semester survey as an activity that helped students learn. The second most common response that was mentioned was working through a problem with another student or in a group; it appeared 16 times. Answering questions individually, cold-calling, and volunteering to answer a question posed by the instructor were not common but still mentioned as effective teaching practices.

Late Semester Survey

At the end of the semester, only three students mentioned listening to a lecture as an effective practice while working with other students still seemed important to participants. Answering questions individually was mentioned 10 times at the end of the semester as opposed to only 5 times in the beginning of the semester. Volunteering and cold calling were still rated by very few students as being effective teaching practices.

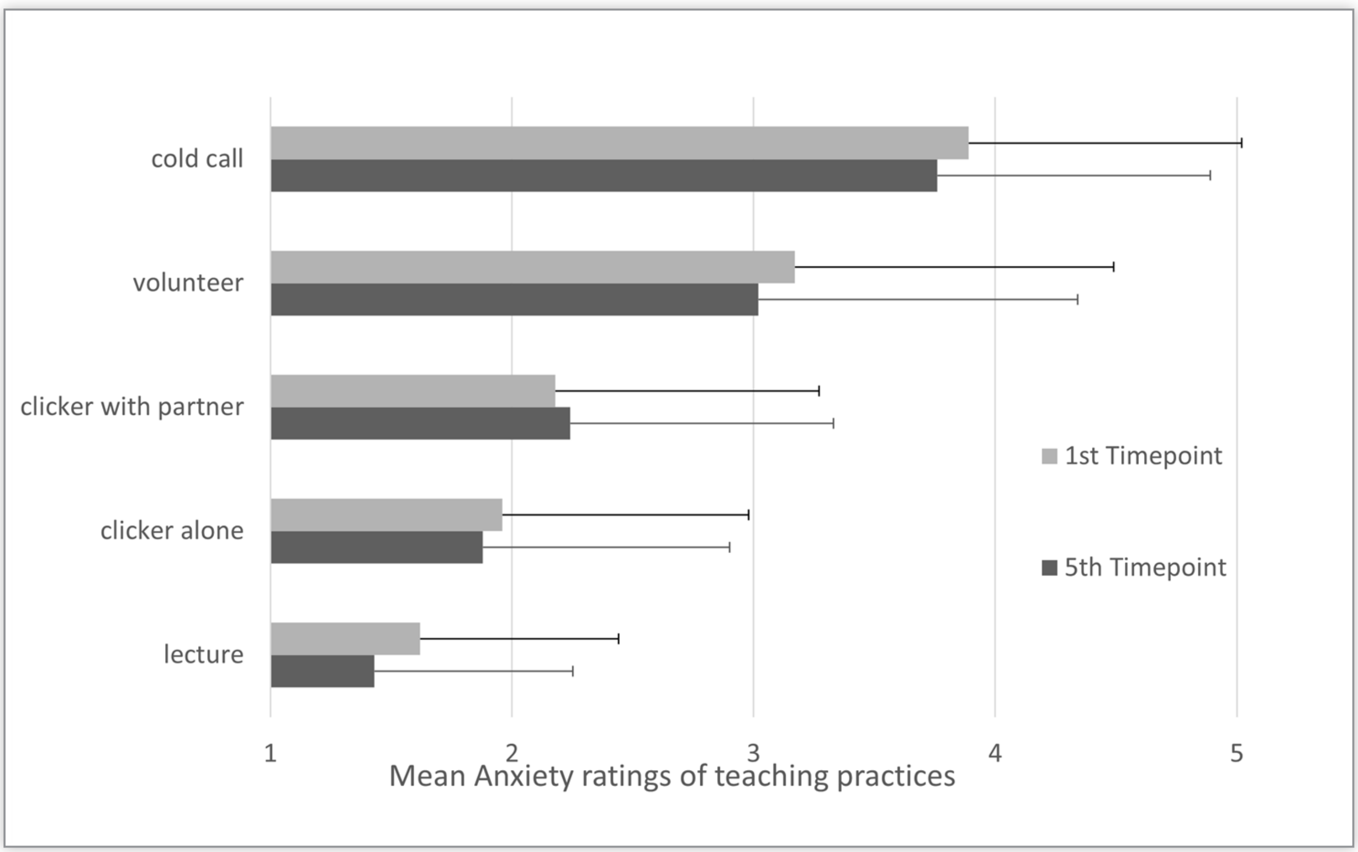

Figure 3. Mean anxiety ratings of teaching practices.

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EBIP in Response	Number of times mentioned		Representative Quote
	1st Timepoint	5th Timepoint	
Listening to instructor give lecture through PPT	18	3	I am a visual learner so watching power points and seeing examples/photos helps me learn better. I also like to take notes and listen rather than do activities. The most helpful thing for me is the lectures and PowerPoints. They help me understand all the knowledge I need to know for each subject/chapter.
Working through problems with another student(s)	16	11	Working with another student in groups of 2 seems to be the most beneficial way of answering for me. That way we can help cover the gaps of understanding. I found working with other students to be helpful because I was able to work through my thought processes with their help and also have them further explain to me the subject.
Volunteering	3	3	Answering questions from an instructor allows me to self-assess my knowledge of the content in that moment. Volunteering to answer a question makes it more likely for me to remember the information as I am actively seeking it out without much anxiety.
Answering questions on my own	5	10	When I work alone to answer a question or do my work It helps me know where I am and what I need to work on. In class assignments, it helped to reflect on what we had learned outside of the classroom before going into the lecture.
Cold calling	5	2	Cold calling does create a necessity for students to both study and learn as well as actively listen / participate. All of this helps the student learn. I remember concepts most when I answer a question posed by the instructor or through cold-calling, whether I know the answer or not. After this experience, I'm sure to retain the information. I suppose it's helping me develop more effective strategies now that I think of it.

Table 6. *Qualitative Results from Student Responses on Effectiveness of EBIPS*

Discussion

Our results showed that students reported significantly lower levels of test anxiety whether they received clicker questions or not. In both groups, an emphasis was placed on mindful breathing, reading exam questions, decoding multiple choice questions, and study techniques. While we did not measure test-taking coping skills in any way, it is worth mentioning that teaching students how to self-regulate and continue to perform in the face of discomfort caused by test anxiety may have had an impact on their self-reported TAI ratings. Teaching students how to use deep diaphragmatic breathing (Magnon et al., 2021) may have had some impact on testing anxiety when we consider that each review session for both groups focused on these skillsets.

Open ended questions asking students about which EBIP they found most helpful and why revealed that each of the EBIPs mentioned in the survey (lecture, working on questions individually, working on questions in groups, volunteering, and cold calling) appeared as a recurring theme in student responses. While it was not surprising that students rated volunteering and cold calling as unhelpful and working through problems as helpful, it was interesting to observe a change in student attitudes about listening to lecture and PowerPoint presentations. In the early survey, this EBIP was mentioned 18 times while in the late survey, only 3

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participants stated that listening to a lecture was a helpful EBIP. Students focused more on working through problems and working with another student.

We suspect that many students entering this course had either not been exposed to or had negative experiences with active learning and rated lecture as a highly valuable practice. After a semester of weekly opportunities to practice applying concepts in class and working actively with their peers, it seemed that students gained an appreciation and realization that active learning is effective. Lecture delivery did not change from the beginning to the end of the semester; students continued to watch lecture videos outside the classroom and perform active learning inside the classroom. These results also suggest that if students see their performance improve, they may be more willing to engage with active learning and cooperative learning even if they associate a level of anxiety with those practices.

Another theme that arose in the late semester student responses was that students rejected the notion that one activity was more helpful than others to the prompt, "For the activities that you found helpful, please explain why they were helpful. Did they help you develop more effective study strategies? If so, what were those strategies?" We observed that in many responses, students mentioned at least two EBIPs they found helpful, whereas in the early survey, they more often chose only one EBIP. While this study did not specifically survey students about their attitudes towards belonging or self-efficacy, students tended to become more comfortable in the classroom as the semester progressed. While teaching style and practices did not change throughout the term, the hope for all instructors is that *students* change. The fact that students choose multiple modalities of learning as beneficial demonstrates a higher level of understanding of themselves as learners.

This study highlights the importance of finding ways to improve student ability to become active participants in their learning process. Instructors can use structured pedagogical tools like clicker questions, exam wrappers, and study skills labs or guide students to achieving more self-awareness through mindfulness practice and exam preparedness skills. Many studies focus on student attitudes toward various teaching practices (England et al., 2017; Hood et al., 2020, 2021; Nguyen et al., 2016) and their performance as a result of a variety of active learning strategies (Rao & DiCarlo, 2001). We also understand the impact of faculty belief systems on student performance. It has been demonstrated that faculty, specifically STEM faculty, who believe that ability is fixed rather than dynamic, have larger racial achievement gaps in their classrooms compared to those with the opposite mindset (Canning et al., 2019). In the face of this information, it is surprising to us that little has been done to help instructors address these issues in the classroom. Our results indicate that instructors may be able to shift student beliefs about themselves and help them develop better attitudes about test taking.

About the Authors

Dalia Salloum is an assistant professor of Biology at Salt Lake Community College. Suzanne Hood serves as an associate professor of Psychology at Bishop's University. Kamie K. Stack is a PhD candidate in Curriculum and Instruction STEM education at the University of Minnesota - Twin Cities. She has a Master of Education in Curriculum and Teaching and a Master of Arts in Curriculum and Teaching: Secondary Mathematics from Columbia Teachers College. She is currently the graduate research assistant on the CAPER grant.

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Use of Consistent Formative Assessments to Engage Students in a Second Semester Human Anatomy and Physiology Course

Ogochukwu Onyiri, PhD

Campbellsville University Harrodsburg, Harrodsburg, KY, USA

Corresponding author: osonyiri@campbellsville.edu

Abstract

In the United States, there is a demand for registered nurses. To be admitted into the nursing program, students need to complete prerequisite courses such as Human Anatomy and Physiology. Many students find Human Anatomy and Physiology challenging due to the nature of the content. Poor performance in Human Anatomy and Physiology can preclude a student from enrolling in the nursing program. In this study, consistent formative assessments were used to engage students in a Human Anatomy and Physiology course, identify knowledge gaps, correct misconceptions, provide feedback to students, and improve learner outcomes and success. Data were collected on students' performance on pre-course assessment, pre-learning reading assignments, formative assessments during learning, and formative assessments post-learning (n=9). A survey was also conducted to determine students' perceptions of their learning experiences on a project-based activity. This study utilized a mixed-methods approach and combined web-based activities, in-class activities, and a group project completed outside of the classroom and presented in the classroom. The mean data for different forms of formative assessment were pre-course assessment (67.8%), pre-learning reading assignments (99%), formative assessments during learning (92.8%), and formative assessments post-learning (87%). The data showed that consistent formative assessments can be used to engage students in active learning, help them prepare for summative assessments, and impact knowledge with positive learner outcomes such as 100% participation in reading assignments, ability to work cooperatively, and a grade of C or better in a Human Anatomy and Physiology course. https://doi.org/10.21692/haps.2024.002

Key words: Anatomy, physiology, nursing, formative assessments

Introduction

In the United States, registered nursing is projected to grow at 6% until 2032 (Bureau of Labor Statistics, 2023). Due to the growth and aging population in the United States of America, many students want to go into the nursing profession to become registered nurses. There is a need for colleges and universities to train nurses to meet the supply and demand for nurses. To be admitted into the nursing program, students are required to complete prerequisite courses. Two of the prerequisite courses required are Human Anatomy and Physiology 1 and 2, including their laboratory courses. These are introductory college STEM (science, technology, engineering, mathematics) courses and are referred to as "gatekeeper" courses for nursing programs (Forgey et al., 2020; Gasiewski et al., 2012). "Gatekeeper" courses are introductory STEM courses where inadequate performance can lead to switching out of a science major (Gasiewski et al., 2012).

Human anatomy and physiology courses are designed to help students learn, and understand the structure, function of the human body, and disease conditions. A good knowledge of human anatomy and physiology is important to the nursing profession and other health fields. Many students experience human anatomy and physiology as challenging due to the nature of the course content, which includes vast amounts of content that require mastery and connections to ideas and concepts. When students find a course challenging, it leads to a lack of intrinsic motivation and an inability to create time to study and learn the material at deeper levels (Grachan & Quinn, 2021; Tracy, et al., 2022). In addition, because of the challenges these students experience, they find it difficult to connect the concepts to real-world situations (Grachan & Quinn, 2021). Poor performance in human anatomy and physiology courses often preclude students from enrolling in the nursing program.

There are several reasons students perform poorly in human anatomy and physiology courses. A study conducted in South Africa showed that ineffective teaching strategies, lack of after-class review sessions or tutoring opportunities, and failure to devote enough study time were among the contributing factors (Mhlongo et al., 2020). In addition, the professor's attitude, instructional strategies, passion, content knowledge, intrinsic motivation, and attitude of the students also impact academic engagement (Gasiewski et al., 2012).

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There is diversity in the backgrounds of students enrolled in human anatomy and physiology courses (Forgey et al., 2020). Some students have knowledge gaps coming into college (Forgey et al., 2020). There are students with a long gap between the time they graduated from high school and when they enrolled to take human anatomy and physiology, as well as students coming into the pre-nursing program without a science background. There are also students without a basic biology prerequisite course in college before taking human anatomy and physiology courses (Forgey et al., 2020). However as evidenced in the research of Forgey et al. (2020), taking a prerequisite course may not predict success in human anatomy and physiology. Some students are parents, full-time employees, caregivers to aging parents, and have limited time to devote to studying the materials. Many factors contribute to poor performance in human anatomy and physiology courses.

It is the responsibility of human anatomy and physiology professors to understand the diversity of students in their classrooms. So that, the professors can provide positive learning environments that cater to the unique needs of each student in their classrooms. The professors remain an important element in engaging students in their learning activities (Brown et al., 2018; Gasiewski et al., 2012; Tracy, et al., 2022). Professors must be intentional in choosing activities that deeply engage students in their learning experiences. Providing opportunities for students to engage with the content, increases the probability of a positive learning outcome (Brown et al., 2018; Gasiewski et al., 2012). According to (Brown et al., 2018; Gasiewski et al., 2012), high course content engagement is associated with high academic achievement. Students will benefit from learning activities that interest and engage them in the classroom for deeper learning of human anatomy and physiology (Brown et al., 2018).

A strategy to engage students in their learning activities is the use of consistent formative assessments (Dimple, 2023). Formative assessment is an evaluation that is done during the learning process to inform both the students and the professor on learning outcomes and knowledge gaps (Chiappetta & Koballa, 2014; Dimple, 2023; Evans et al., 2014). Formative assessment can be done before the learning process (Chiappetta & Koballa, 2014), during the learning process (Chiappetta & Koballa, 2014; Dimple, 2023), and at the end of the learning process (Chiappetta & Koballa, 2014). Students are provided opportunities for pre-class activities such as reading assignments, research, and worksheets. Students can also be evaluated for their understanding of a concept during the learning process and post learning such as group presentations, demonstration of learning, short response prompts, quizzes, question, and answer sessions. Throughout the learning process, students are consistently being held accountable for their learning and engagement with the content. Students get immediate and valuable feedback on their learning outcomes (Dimple, 2023; Kulasegaram & Rangachari; 2018). Formative assessment also provides the teacher feedback on what students know and the knowledge gaps to enable the teacher to plan for future instructions (Chiappetta & Koballa, 2014; Dimple, 2023; Evans et al., 2014).

Continuous formative assessments spread across the span of the course can be used to engage students (Evans et al., 2014). Students are likely to do well in a course when multiple opportunities are provided to review, practice, and master the materials presented in class. For formative assessments to be effective, there should be learning objectives (Dimple, 2023; Kulasegaram & Rangachari, 2018) to help the professors and students evaluate learner outcomes (Kulasegaram & Rangachari, 2018). The goals of formative assessments are to help students master the content, prepare for summative assessments, and grow in the content knowledge for future applications (Dimple, 2023).

Purpose of Study

In this study, consistent formative assessments were used to engage students in a Human Anatomy and Physiology course, identify knowledge gaps, correct misconceptions, provide feedback to students, and improve learner outcomes and success. Success in this study is defined as a final course grade of C or better (Forgey et al., 2020). According to (Gasiewski et al., 2012), lack of academic engagement in a “gatekeeper” course is a primary reason for a student to switch out of a science major. Strategies used in this study can be explored by other professors to engage their students in their academic experiences. Recommendations from this study can potentially have a positive impact on students in a STEM course.

Methods

This study was conducted in a second-semester human anatomy and physiology course during the spring semester of 2023. The course was for 16 weeks, a three-contact hour of lecture per week with once-a-week class meetings. In addition to the three lecture hours, there is a separate human anatomy and physiology laboratory course. Data were only collected for the lecture portion of the course. Each student had completed a first-semester human anatomy and physiology course. The course started with eleven students (n=11). However, only nine (n=9) stayed until the end of the course. Data for the two students who dropped the course were not included in this research. Due to the small sample size, data for gender and age were not included in this study. This study used a Learning Management System (LMS) for the quiz-based activities and a digital learning platform embedded within the LMS for the reading assignments.

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Quantitative data

Pre-course assessment

On the first day of the course, students were pre-assessed on their knowledge of human anatomy and physiology 1. The preassessment had 10 multiple-choice questions from concepts covered in human anatomy and physiology 1. The concepts tested on the pre-course assessment include homeostasis, levels of biological organization, properties of living things, cellular transport, functions of epithelial tissue, cell connections and barrier, tissue damage and inflammation, layers of the epidermis, osteoclast activity, and oxygen transporter. These are concepts mostly covered in human anatomy and physiology 1. Students are expected to come into human anatomy and physiology 2 with good knowledge of these concepts. The pre-course assessment was administered on the LMS but completed in the classroom with the use of a laptop. Students were informed that the pre-course assessment did not count against them for a grade.

Pre-learning formative assessment

Pre-learning reading assignments were completed at home by the students. Reading assignments were completed using the materials in the digital learning platform embedded within the LMS. Students were assigned reading assignments throughout the semester. Reading assignments were assigned based on the chapter/concepts to be discussed for the week of the assignment. Students were required to spend 3-4 hours per week on reading assignments. As they completed each reading assignment, students responded to questions based on the concepts to evaluate their reading comprehension of the concepts. The first reading assignment was assigned after the first-course meeting. The last reading assignment was completed before the final exam. Students were not assigned reading assignments during exam weeks and spring break. Each reading assignment constituted a pre-learning activity for the students. Students were given credit for completing each reading assignment. All the reading assignment assessments were automatically graded with opportunities for multiple attempts for full credit. A total of seven graded reading assignments were used for this course. Students were asked questions based on the assigned chapter for warm-up and discussion within the first 5-10 minutes in the classroom.

Formative assessments during learning

The following activities were used to engage students and evaluate their understanding during learning in the classroom: Group work/research and presentation, worksheets, written assessments, and peer teaching. Formative assessments were done every 20-25 minutes of teaching to evaluate students' understanding of a concept. For the group work, students were assigned to groups based on proximity, 2-3 students per group. Each group was given a topic with specific learning objectives. Students researched their topics, discussed among themselves through peer teaching, and presented their understanding of the concepts to the class. Opportunities were also provided for students in other groups to ask questions to the presenting students. Predetermined questions were used for formative assessment of students understanding of concepts in the classroom. There were several formative assessments used during learning activities, but only six were recorded as grades for the students. Students were given opportunities to correct their misconceptions or identify knowledge gaps in the classroom. Interventions were provided as needed.

Formative assessments post-learning

Three post-learning activities were graded for this study. One multiple-choice quiz was completed on the LMS, one worksheet was completed in the classroom, and one group project on digestion and metabolism catered to students' interests and culture.

Students chose meals that they enjoyed at home for the project on digestion and metabolism. About three students worked in a group to complete this project. Students were given 2 weeks to complete this project (get together, research, and create PowerPoint slides for presentation in the classroom). The meals students chose for this project included tortillas made with beans, cheese, beef, vegetables, and homemade chicken alfredo fettuccine. Each meal must contain carbohydrates, proteins, and lipids.

The expectations for this project were explained to the students at the beginning of the semester and three weeks from the day of the presentation. The concepts associated with digestion and metabolism were also discussed with the students before the project/presentation. Students were evaluated for their understanding through predetermined questions during presentations. The students asked questions to students doing the presentation, students doing the presentation asked questions to students not doing the presentation, providing opportunities for discussions and interactions in the classroom. Each group was given 10-15 minutes for their presentation. A few students volunteered to bring the meals chosen for their project to class. Students learned about digestion and metabolism and enjoyed the meals together.

Some of the activities used in this study were also listed as forms of formative assessment by (Dimple, 2023). Formative assessments should be balanced with summative assessments to get accurate information on a student's academic ability (Dimple, 2023). Formative assessments accounted for 29.08% of the final grade in the course used for this study. Students brought their laptops to the classroom for each course meeting. The different forms of formative assessment, number of assessments graded, contributions to the final course grade, sample learning objectives, sample questions, or prompts are shown in Table 1.

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The following topics were covered for this course: cardiovascular system (blood, heart, blood vessels, and circulation), lymphatic system and immunity, respiratory system, digestive system, nutrition, metabolism, and temperature regulation, urinary system, endocrine system, reproductive system, development, growth, aging, and genetics. Activities used for this research cut across these topics.

Qualitative data

A survey was conducted on the LMS to explore students' experiences on one of the group projects used in the course. Students responded to questions on their learning experience, suggestions for improvement of future projects, helpful study strategies for the course, and recommendations for future students. Eight students completed the survey. In addition, qualitative observations were used to record student engagement, discussions, and interactions with each other. Thumbs up or thumbs down were used as informal nonverbal ways to evaluate students' perceptions of learning.

This study used a mixed-methods approach. Quantitative data provided information on students' performance on formative assessments and qualitative data provided information on student perceptions of their learning experience.

Number Used	Type	Percent Added to Final Grade	Learning Objectives Aligned to Assessment	Sample Prompts Questions or Activities
1	Pre-course assessment	0%	Students will be able to respond to the characteristics of life and identify the mechanism for glucose transport	Which of the following is consistent with homeostasis? The changes an organism undergoes through time is _____________. Glucose is transported across the plasma membrane by ______________ process.
7	Formative assessments: pre-learning reading assignments with generated questions	11.56%	Students will be able to: Describe the interventricular septum. Recall the definition of the atrial ventricular valves. Differentiate between the two layers of the serous pericardium.	Reading assignments and evaluation of reading comprehension. Students are required to come into the classroom ready to ask questions and discuss concepts. The class meetings start with a warmup activity, usually the first 5-10 minutes of class. Warmup activities prepare students for learning. During warmups, students respond to questions or prompts based on previous learning or the concepts to be learned. Example: Identify the AV valves.
6	Formative assessments: during learning.	9.3%	Students will be able to state the functions of the tonsils, lymph nodes, thymus gland, and spleen in immunity; State functions of the kidneys; List the parts of the nephrons; Discuss filtration, reabsorption, and secretion, and two hormonal mechanisms for the concentration of urine.	Group work/presentation on assigned topics, written assessment, peer teaching, and worksheets. For example, discuss the roles of the following organs in immunity: lymphatic tonsils, lymph nodes, thymus gland, and spleen. Students are usually given 10-15 minutes to work on topics before evaluation of their understanding. Examples of questions or prompts on a written assessment: Write 5 functions of the kidneys. What are the four parts of the nephron? Discuss filtration, reabsorption, and secretion. Discuss two hormonal mechanisms for urine concentration.
3	Formative assessments: post-learning	8.22%	Students will be able to: Differentiate between lymphatic capillaries and blood capillaries; Identify functions of the digestive system; Explain the histology of the digestive tract wall; Identify the carbohydrate, protein, and lipid content of a meal; Describe how the digestive system breaks down each food group into monomers; Describe how each monomer is absorbed from the small intestine into the hepatic portal system; Illustrate how each monomer is converted to ATP for cellular work; State how this project has informed their understanding of digestion and metabolism; Complete a PowerPoint presentation in the classroom and respond to questions on the project; State the future applications of the knowledge gained from the project.	Quiz, group project, and worksheet (students worked in groups to summarize their understanding of concepts.) Examples: How do lymphatic capillaries differ from blood capillaries?, What are the major functions of the digestive system?, Describe the major tunics of the digestive tract wall from the inside to the outside, What substances are directly absorbed from the stomach?, How are carbohydrate monomers absorbed through the small intestine?, How will you apply the knowledge gained from this project in the future?

Table 1. *Forms of formative assessment aligned to sample learning objectives and prompts or questions.*

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Statistical Analyses

The data were exported into an Excel spreadsheet from the LMS. The mean, standard deviation, and 95% confidence interval (CI) of the lower and upper limits of the mean were calculated for each formative assessment using Excel version 16.82 (Microsoft 2024, USA).

Results

The summary data for the pre-course assessment, pre-learning formative reading assignments, formative assessments during learning, and formative assessments post-learning are shown in (Table 2).

Table 2 shows the mean, standard deviation, and ± 95% CI of the mean for each of the formative assessments used in this study.

Error bars in Figure 1 represent ± 95% CI of each mean for the forms of formative assessment. The class mean for the pre-course assessment is 67.8% (Table 2; Figure 1). For the individual items on the quiz, students who gave correct responses were in the following order: 100% for levels of biological organization and functions of epithelial tissue; 89% for homeostasis and osteoclast activity; 78% for layers of the epidermis and oxygen transporter; 67% for cell connections; 33% for property of living things, and 22% for tissue damage and inflammation and cellular transport (Figure 2).

The participation rate for the reading assignments (formative assessment pre-learning) is 100% and the mean score is 99% (Table 2; Figure 1). The mean score for the formative assessment during learning is 92.8% (Table 2; Figure 1). The mean score for formative assessment post-learning is 86.9% (Table 2; Figure 1).

Types of formative assessment	Pre-course assessment	Pre-learning reading assignments	Formative assessments during learning	Formative assessments post learning
Number of graded work (n)	1	7	6	3
Mean	67.8	99.1	92.8	87
STD	13	2.32	8.61	6.9
95% CI	8.5	1.52	5.62	4.5
Number of students (n=9)				

Table 2. *Summary data of students' performance on the different forms of formative assessment.*

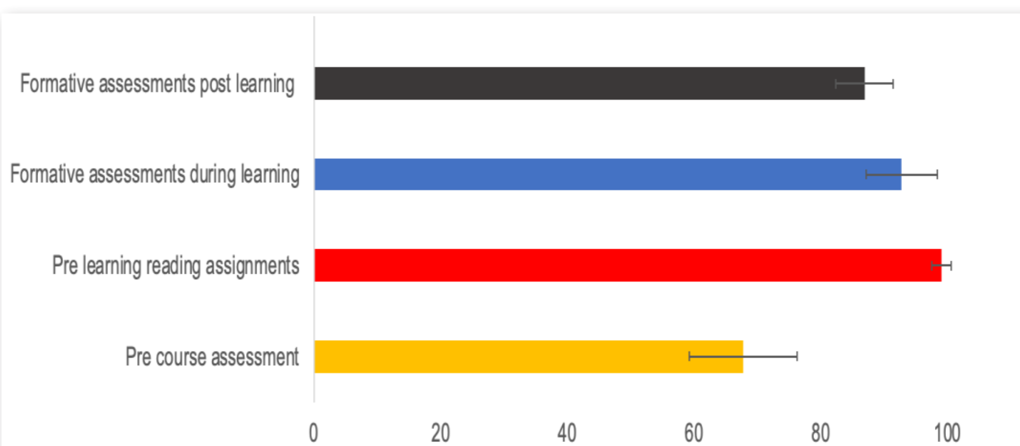

Figure 1. *The mean performance of students in the different forms of formative assessment ± 95% CI (n=9).*

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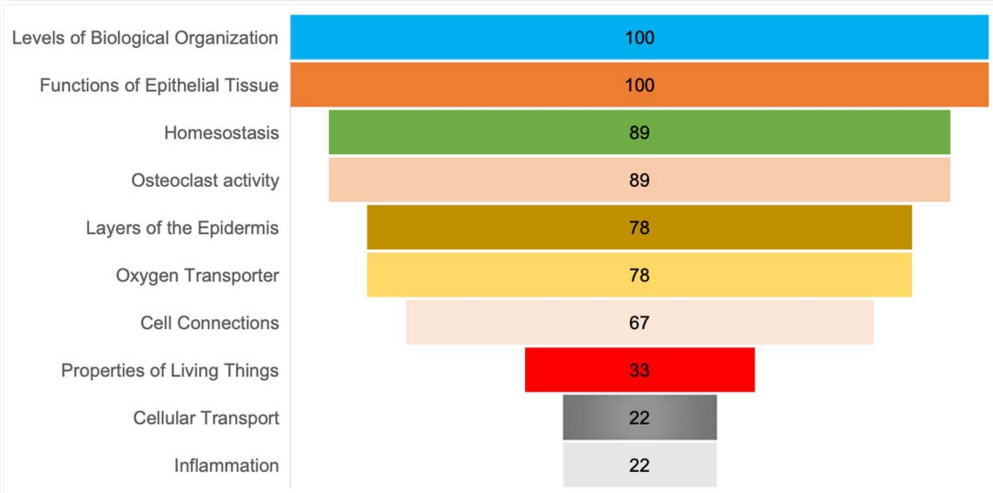

Figure 2. *The percentage of students who gave correct responses in the pre-course assessment (n=9)*

Discussion

Pre-Course Assessment

The data for the pre-course assessment showed that most students performed well in levels of biological organization, functions of epithelial tissue, homeostasis, osteoclast activity, layers of the epidermis, and oxygen transporter (Figure 2). However, there were still knowledge gaps in some concepts that needed to be accommodated in future instructions. Students struggled with the properties of living things, cellular transport, and inflammation. According to Chiappetta & Koballa (2014), preassessment is diagnostic and serves to determine what students already know, so that educators can meet the learning needs of students through instructions. The preassessment provided the students and professor with immediate feedback and helped the professor plan for future instructions (Kulasegaram & Rangachari, 2018). Lazarowitz & Lieb (2006), used preassessment in a biology course to evaluate students' basic knowledge in the respiratory system. Lazarowitz & Lieb (2006), found that students had misconceptions and basic knowledge gaps on the respiratory system. This study also revealed knowledge gaps and misconceptions in basic knowledge in some of the concepts evaluated during the preassessment.

Concepts such as properties of living things, cellular transport, and inflammation are parts of Human Anatomy and Physiology 1 curriculum at most colleges and universities. Students are expected to come into Human Anatomy and Physiology 2 with a basic understanding of the properties of living things, cellular transport, and inflammation. Knowledge gaps or misconceptions could be attributed to students' learning difficulties (Lazarowitz & Lieb, 2006). Learning difficulties could be explained by differences in academic backgrounds, abilities, cognitive stages, and learning styles (Gasiewski et al., 2012; Lazarowitz & Lieb, 2006). The inability to integrate learning across related concepts can lead to knowledge gaps and misconceptions. It is the role of the professor to understand the backgrounds of students in the classroom, plan, and design instructions to accommodate diverse learners. The preassessment data were used to inform instructions. Poorly mastered concepts such as cell-to-cell connections, inflammation, cellular transport, and properties of living things were reviewed with the students. Cell-to-cell connections are relevant to the gap junctions and intercalated discs of heart muscle cells and are a concept students will encounter in the generation of action potential in cardiac muscles. Tight junctions of the intestinal epithelium are a concept students will encounter in the digestive system. Inflammation is relevant to the body's response to tissue damage, a concept that students will encounter in immunity and some human diseases. Cellular transport mechanisms (diffusion, osmosis, facilitated diffusion, and active transport) are relevant to urine production. Through this preassessment, students were reminded of the connection between Human Anatomy and Physiology 1 and Human Anatomy and Physiology 2. Students were re-taught these concepts for better understanding. In addition, throughout the course when concepts from Anatomy and Physiology 1 were encountered, they were connected, helping students to build on existing knowledge.

Preassessment when combined with feedback has a positive impact on students learning and performance (Kulasegaram & Rangachari, 2018; Ivanistkaya et al., 2008). The pre-course assessment provided the professor with baseline knowledge of the students coming into Human Anatomy

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and Physiology 2. It also helped to identify and address misconceptions. It also provided students with immediate feedback and review opportunities for poorly mastered concepts. Providing feedback to students promotes student engagement and learning (Gasiewski et al., 2012; Kulasegaram & Rangachari, 2018).

Formative Assessment of Pre-learning Reading Assignments

The data for the pre-learning reading activities are shown in (Table 2; Figure 1). The reading assignments were engaging and provided opportunities for students to pre-read the text, annotate specific content, respond to prompts generated, review, get immediate feedback, and write down their questions to be discussed in the classroom. When students are provided opportunities to ask questions, their engagement and learning are improved (Gasiewski et al., 2012). One hundred percent of the students participated in the reading assignments and students received grades for their completion of the assignments. The students had the opportunity for multiple attempts to earn full credit. The use of graded reading assignments as formative assessments can be motivating for students. According to (Kerr & Frese, 2017), lack of motivation is one of the reasons college students fail to complete course readings. Reading assignments completion among undergraduate students is low (Kerr & Frese, 2017; St Clair-Thompson et al., 2017), between 20-30% (Kerr & Frese, 2017). In this study, 100% of the students completed the reading assignments as they were tied to the final course grade. All the students responded positively to this activity as evidenced by the 100% participation rate, and a mean score of 99% (Table 2, Figure 1). The reading assignments provided opportunities for students to come to class with discussion questions. Those questions were discussed in the classroom, providing additional learning opportunities. Students are more likely to complete reading assignments when they earn points for the reading and points earned become part of the course final grade. Findings from St Clair-Thompson et al. (2017) also showed that students would complete reading assignments if they were part of the course requirements. Students should be provided opportunities for minimally graded assignments and should earn points for completed work (Hanstedt, 2020). Combining in-class activities with a web-based activity can increase students' engagement with the course content (Gasiewski et al., 2012).

Formative Assessment During Learning in The Classroom

This study utilized a variety of formative assessment strategies (Table 1), which included formative written assessments. According to Carter & Prevost (2023), short response prompts provide opportunities for students to think deeply and construct responses that connect to different concepts. Formative written assessments help students integrate learning within concepts and across concepts. Formative assessments when aligned with the learning objectives are effective (Kulasegaram & Rangachari, 2018; Dimple, 2023) in helping students engage and learn at higher levels. The data for the in-class learning activities for the students are shown in (Table 2; Figure 1). Formative assessments of students during learning redirect the focus to "what was learned" rather than "what was taught" (Dimple, 2023). Formative assessment provides immediate data in the classroom. It helps the professor decide if to move forward with instructions on new concepts or to provide additional learning opportunities for concepts already discussed. For example, in one of the written formative assessments, students were able to provide a basic understanding of the concepts tested in the assessment (Table 3). When students were asked to list 5 functions of the kidneys, one hundred percent of the students were able to list 5 functions of the kidneys. However, when students were asked to discuss two hormones responsible for urine concentration and volume, one hundred percent of the students listed at least two hormones responsible for urine concentration and volume but none of the students could explain the role of any of the hormones in urine concentration and volume. These data helped the professor to offer additional explanations on the role of antidiuretic hormone and renin-angiotensin-aldosterone on urine concentration and volume. Additional learning opportunities were provided through illustrations, direct teaching, or reference to resources when students demonstrated poor understanding of already taught concepts or were unable to explain concepts to the professor's satisfaction. In addition, group work, worksheets, and peer teaching were used. In this study, the formative assessments were aligned with the learning objectives and helped students to learn at higher levels (Table 1 and Table 3). In some cases, nonverbal information was obtained from students to get information on learner perception. Also, the professor observations of the look on the students' faces. If facial expression signaled confusion, the student was given the attention to address the confusion. Sample student responses to a written formative assessment completed in the classroom are shown in (Table 3).

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Formative written assessment question or prompt	Sample students' responses
1. Write 5 functions of the kidneys:	Student 1: "Excretion of waste products." "Regulation of blood volume and pressure." "Regulation of extracellular fluid pH." "Regulation of red blood cell synthesis-secretes erythropoietin." "Regulation of vitamin D synthesis."
2. What are the 4 parts of the nephrons?	Student 2: "Renal corpuscle, proximal convoluted tubule, loop of Henle, distal convoluted tubule."
3. Discuss filtration, reabsorption, and secretion:	Student 3: "Filtration-movement of fluid across filtration membrane." "Tubular reabsorption- transport of water and solutes from the filtrate back to the blood. Mostly in proximal convoluted tubule." "Secretion- movement of nonfiltered substances from blood to filtrate."
4. Discuss two hormonal mechanisms for urine concentration:	Student 4: "Renin-angiotensis-aldosterone." "ADH." "These both effect urine volume and concentration."

Table 3. *Sample students' responses from a written formative assessment.*

Formative Assessment After Learning

The data for the formative assessment post-learning are shown in (Table 2; Figure 1). For most of the formative assessments at the end of learning, the last 10-15 minutes of class were used to summarize what was learned and provide opportunities for students to demonstrate mastery of the concepts, ask questions, and correct misconceptions. In this study, a quiz on LMS, exit slips, and group project/presentation were some of the post-learning activities. These instructional approaches support students learning in the classroom (Gasiewski et al., 2012). Based on the data of students' performance on the formative assessment (Table 2; Figure 1), students were engaged on average in their learning activities. The group project on digestion and metabolism provided additional learning opportunities for students to collaborate and support each other's learning. During the presentation, students were asked questions by the professor and non-presenting students. Presenting students also asked non-presenting students questions. Providing opportunities for student-student interactions, student-content interaction, and student-professor interaction. During these interactions, knowledge gaps were identified and bridged, and misconceptions were corrected by the professor. Additional interventions were provided to individual students on a need-basis. As part of the project, students ate together and learned together in the classroom. Students are more likely to engage in their learning activities when the professor consistently provides opportunities for students to demonstrate learning through formative assessments. When students know that each day in the classroom counts toward their final grade that is motivational for them. Through formative assessments, students get immediate feedback and understand when additional efforts are required to enhance grades (Jiang, 2023). Students' responses to the survey on the project on digestion and metabolism are shown in (Table 4).

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Question or Prompt	Students' responses
1. What was the best part of the project?	"The best part about the project was understanding that food can be broken down to simpler materials or items." "It gives us a hands on experience for learning." "The best part was working together with my classmates." "I enjoyed getting to work on the project with my friends and bringing in the food. I think it was fun eating the cooked food in class." "The best part of the project on digestion was when I was able to learn the differences between lipids, carbs, and proteins. I really enjoyed learning about how my body uses the things I eat to grow and how I need to fuel my body." "The best part is taking the material learned and being able to apply it to real life situations/culture." "The best part of this project is that we are learning about where all of the foods go that we eat and what they do for the human body. This is extremely important for a person like me, because I like to workout and be healthy which means I need to know about what foods are good to put into your body and which foods are not." "I Learned why there are two cycle in of the citric acid cycle. It goes through twice, because it needs to process two pyruvate molecules."
2. What needs to be improved on the project?	Seven of the students stated that they needed more time to complete the project. "A part that could be improved as I suggested earlier is suggesting every group cooks and allowing more time to work on the presentation." Only one student stated: "Nothing really that caught my attention."
3. Do you think this project should replace teaching digestion and metabolism next semester?	"Yes, because doing the project gives you a better understanding of how digestion and metabolism work in the body. It can also add a fun break in the class to make it more interesting." "No. Some people learn better with lecture." "I think it would make it easier to learn the criteria. When students are able to research topics on their own they seem to retain the information better than having slides shown to them by the teachers." "I don't think so because I feel like I wouldn't have known the material if we hadn't gone over it in class as well. The PowerPoint, definitely helped me understand the material better, so I would not replace the project with teaching." "I do not feel like this project should replace teaching the topics because you know more than we do. You explain things better than we do. Students also don't pay too much attention when presentations from students happen." "I think if anything if possible move the digestive system unit up so it allows more time for the project but I would not replace anything." I don't think the project should replace the teaching of the topic as a whole because I feel like the way we did it this semester was good. Learning about the digestive system first and then given the project which allowed to learn more about digestion and metabolism." "I actually like that some people are not gifted at just relying on exams to help with their grades. This way the get to learn the information by working it with it themselves and reading and researching instead of being told the information."
4. What study strategies work for you in this course?	The students stated that completing the study guides, use of flashcards, studying in groups, asking the professor questions for clarification, and reading the chapters

Table 4. *Students' responses from the survey on the digestion and metabolism survey.*

Question 1.

Clearly, from the students' perspective, the project had a positive impact on their learning. They learned concepts associated with digestion and metabolism, they learned collaboratively, and it was fun eating the meals in the classroom and immediately connecting learning to real-life situations. One of the students suggested that in the future, all students should bring food to the class. This is a great suggestion, but it is important to let students know that bringing food to the class for a project like this is optional.

Question 2

Seven out of the eight students stated that they would have preferred additional time (more than 2 weeks) to work on this project. This is feedback from the students that will help improve future project-based learning experiences. Students were allowed two weeks to complete this project and more time could be beneficial to their learning. This also highlights the importance of students' perspectives on their learning experiences in the classroom. In the future, students will be given more time to work on projects that require work outside of the classroom.

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Question 3

Most of the students were opposed to the idea of replacing instructions in the classroom with the project as evidenced in their responses. The students' responses highlight the need for professors to provide multiple opportunities for students to learn and relearn concepts in human anatomy and physiology. According to Kulasegaram & Rangachari (2018), available time can limit a professor's ability to offer multiple opportunities to learn concepts in the classroom. The use of consistent formative assessments during instructions creates an active learning environment and supports students' engagement as shown in this study.

Question 4

The students stated that study guides, asking the professor questions, use of flashcards, reading the chapters, and studying in groups helped them prepare for exams in this course. Interactions with the content, collaborative learning/group work, and professor strategies as used in this study have been shown to have a positive impact on student engagement (Gasiewski et al., 2012).

Qualitative data enrich quantitative data and provide information on students' perceptions of their learning experiences (Gasiewski et al., 2012). Qualitative data can also provide opportunities for students to provide suggestions/recommendations on how to improve instructions and cater to students' needs in the classroom—leading to equity in the classroom.

Limitations

The study was conducted for one semester and the data were obtained from a sample size of 9. The author acknowledges that large class size, physical structure, and available time can impact the ability to use consistent formative assessments in the classroom (Kulasegaram & Rangachari, 2018). In addition, course attendance issues, and resource gaps such as access to technology (computers, learning management systems, and digital learning platforms can limit the use of some of the strategies used in this study. The survey responses are associated with a learning experience from a specific project and may not reflect the full range of learning experiences from the course.

Recommendations

As part of the survey, students provided suggestions for future students on strategies for a successful outcome in Human Anatomy and Physiology. The students recommended good study skills, taking notes during lectures, engaging in learning activities, reading the assigned chapters, asking questions when confused about a concept, use of flashcards, and study groups. These are strategies that professors can share with their students and have on the course syllabus.

Consistent formative assessments can be applied to larger class sizes with LMS-based quizzes, publisher-provided digital learning platform-based assignments, written formative assessments, group work, project-based learning, oral group assessments, and whole-class question-and-answer sessions. Google Forms can be used for multiple-choice questions, and written responses. Student response systems such as clickers and Kahoot could be used for large class sizes. Portfolios and learning logs, self-assessments, and individualized problem-solving exercises can be included in a formative assessment plan for the semester (Kulasegaram & Rangachari, 2018)

Conclusions

Formative assessments provide immediate feedback to students and the professor on what the students have mastered, knowledge gaps, opportunities to correct misconceptions, and additional learning opportunities. Formative assessments should be frequent in difficult courses such as Human Anatomy and Physiology. Providing students with diversity in formative assessments helps evaluate students understanding of the relationship between structure and function. Knowledge gained during formative assessments will help the students prepare for summative assessments, support learning/help the professor plan for instructions in the classroom, and prepare the students for future instructions.

Feedback from the students' survey shows that students were engaged in the course and benefited from the strategies used such as the group project, reading the chapters, and the opportunity to ask questions in the classroom. Students engaged with the content pre-learning, in the classroom, and learned collaboratively, and independently. Students were provided the opportunities for them to grow in their knowledge; while acquiring life skills such as the ability to do research, speak in front of an audience, cooperate, and function as a team member. Positive learner outcomes from this study: 100% of the students completed their reading assignments as compared to 20-30% reported by (Kerr & Frese, 2017). This study combined web-based activities and in-class activities to promote student academic engagement. One hundred percent of the students passed with a grade of C and above with a class average of B. A study conducted in South Africa showed the passing rates for student nurses in Human Anatomy and Physiology across six campuses were between 54% and 70% in 2014 and 2017 respectively (Mhlongo et al., 2020). Students must engage with the content to experience academic success.

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Several factors affect students' performance in the classroom and the professor and students have roles to play (Gasiewski et al., 2012; Tracy, et al., 2022), in achieving academic success for the students in the classroom. Each day in the classroom, students received immediate feedback on their understanding of concepts. When it was determined that students did not understand a concept. The concept was discussed again-providing opportunities for students to correct misconceptions and learn at a deeper level. Students were able to reflect on their learning through opportunities to revisit poorly understood concepts, embraced learning, and constructed an understanding of challenging concepts.

The motivation to engage with the course content and learn is driven by the reason(s) the students are taking the course (Gasiewski et al., 2012). Gasiewski et al. (2012), showed that students in the premed program were more engaged/motivated than students taking a STEM course to meet a graduation requirement. Regardless of the reason why a student is taking a course, the professor has a role to play in providing an environment where students can experience academic engagement.

In the future, formative writing assessments, culturally responsive projects, and project-based learning will be largely employed to engage students and help them show mastery of concepts discussed in the course.

Acknowledgments

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About the author

Dr. Ogochukwu Onyiri is an associate professor of biology in the Department of Biology at Campbellsville University Harrodsburg, KY. She currently teaches Human Anatomy and Physiology 1 and 2, including laboratory courses, and Medical Microbiology for pre-nursing students. She also teaches non-majors biology courses, and Methods of Teaching Science in Middle and Secondary Schools, a graduate-level course. She combines her skills as a certified educator and biologist to engage her students in the classroom. Her research interest is in how students learn best and strategies for engaging students in the classroom.

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A “Puzzling Physiology and Nobel Laureates” Game: Engaging BSN Students in Physiology & Medicine

Angela L. Mahaffey, PhD

Marcella Niehoff School of Nursing, Loyola University Chicago, Chicago, IL, USA

Corresponding author: amahaf1@luc.edu

Abstract

This article details a ‘puzzling’ teaching and learning method to engage undergraduate nursing (BSN) and exercise sciences (BSES) students in physiology or medicine Nobel Prize-winning discoveries, while reviewing course material through the “Puzzling Physiology and Nobel Laureates” (PPNL) game. The qualitative evaluations of 117 undergraduate BSN and BSES students revealed that 95% and 96%, respectively, agreed the game provided an opportunity to utilize critical thinking and problem-solving skillsets. Moreover, 96% of the 117 anonymous student respondents voted on increasing the number of PPNL game sessions per semester, and 94% agreeing the gamified learning strategy should be offered in subsequent classes as well. Interestingly, nearly 90% agreed that the learning experience was ‘fun’, and that it increased awareness of physiology and/or medicine discoveries. The style of the “Puzzling Physiology and Nobel Laureates” game lends to its reproducibility in a wide array of physiology courses for both majors and nonmajors. https://doi.org/10.21692/haps.2024.006

Key words: game; health professions students; undergraduate nursing; human physiology

Introduction

An Undergraduate Human Physiology for Health Sciences Course

A Loyola University Chicago School of Nursing health professions course in human physiology is offered to both the BSN (Bachelor of Science in Nursing) and the BSES (Bachelor of Science in Exercise Sciences) students during the spring. Prerequisite courses for enrollees are chemistry and anatomy, offered in the preceding fall semester. The demographics for the Spring 2023 semester courses taught by the author correspond with those from the previous semester enrollments between 2018 and 2022 (n = 148), and are as follows: 126 female students, 22 male students (n = 22), 117 BSN majors, 27 BSES majors, and 4 students from other majors. Since 2017, this 3-credit hour course has offered a 1-credit hour corequisite face-to-face 2D virtual laboratory (Mahaffey, 2018), in-lecture medical case studies, online exams, augmented reality learning tools, interactive peer games, memory tools such as mnemonics (Mahaffey, 2019; Mahaffey, 2021; Mahaffey, 2022). It also employs teaching and learning approaches geared toward BSN and BSES students (Mahaffey, 2023). The significant role of human physiology in BSN curricula is exhibited in the Nursing Licensure Exam Test Plan (NCLEX), as outlined by the National Council of State Boards of Nursing NCLEX Test Plan (April 2019 – March 2023) (National Council of State Boards of Nursing, 2019). Comparably, BSES majors seeking to complete licensure through the American College of Sports Medicine (ACSM) (such as the ACSM Certified Exercise Physiologist (ACSM-EP) and Clinical Exercise Physiologist (CEP) exams) complete prerequisite studies in both anatomy and human physiology (Committee on Certification and Registry Boards [CCRB], 2022). Given the hefty curricula of both programs, discussions on cognitive overload prevention and improving student engagement began to emerge.

Tackling Cognitive Overload in Undergraduate Science Courses Using Student Engagement Projects

The Cognitive Load Theory formalized in a 1956 *Psychological Review* article, by George A. Miller (Miller, 1956) was the foundation of what has been coined “Miller’s Law”. This concept is loosely hypothesized as the ability of individuals to retain 7 ± 2 items in a period that would later qualify as “short-term” memory. Miller’s Law did elucidate two important factors: information processing and retention. Furthermore, it became the precursor to numerous hypotheses and commentaries on informational load in teaching and learning practices, as well as considerations in curriculum design. Hypotheses of cognitive load in teaching and learning have been explored in courses such as mathematics (Beserra et al., 2014), medical education (Bailey et al., 2021), biostatistics (Guzman et al., 2019), pharmacology (Kaylor, 2014), and simulated learning (Sevcenko et al., 2021). Considering cognitive load in health professions education, BSN programs generally require 120 – 130 credit hours, including science courses such as psychology, statistics, anatomy, chemistry, physiology, pathophysiology, microbiology,

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nutrition, and pharmacology (Jensen et al., 2018), coupled with clinical simulation and practice (Nursing License Map with edX, 2022). According to the Princeton Review's "What to Expect in Medical School", beyond the four years of pre-med bachelor's degree prerequisite, there are four years of medical school preceding the three to seven years of residency (The Princeton Review, 2022). The volume of knowledge one is to acquire in the health professions curricula spans a broad array of content learned in theory and practice. Additionally, success with licensure exams for BSN, BSES, and MD candidates is contingent upon innumerable study hours and reviews of test plans (Committee on Certification and Registry Boards, [CCRB], 2022; Federation of State Medical Boards [FSMB], National Board of Medical Examiners [NBME], 2023; National Council of State Boards of Nursing, 2019). Interestingly, this examination of cognitive load is not relegated to student learning but can also be observed in instructor training (Ong & Tasir, 2015), highlighting this pedagogical concern's extensiveness.

As an effort to circumvent informational overload and to increase student engagement, STEM and health sciences instructors have designed engaging and interactive learning simulations through crossword puzzles, simulated escape rooms, board games, and online anatomy-physiology games (Cardozo et al., 2016; Gómez-Urquiza et al., 2019; Hsu et al., 2023; Kane et al., 2022; Luchi et al., 2019; Taspinar et al., 2016). Educational gaming modules may help to motivate learning while abating the informational overload concerns (Huang, 2011). Today, human physiology students find interactive exercises more helpful than the sole use of an assigned text, which is why more publishers have developed supplemental e-modules to complement textbooks. A 2018 A*dvances in Physiology Education* article by Lisa Anderson highlights the aforementioned and provides qualitative survey results for 140 student participants in an undergraduate Human Physiology course ranking eight (8) resources; the top being critical thinking exercises and the fifth was a textbook (Anderson, 2018). Finding a teaching method that integrates both critical thinking exercises and textbook resources would likely improve student knowledge of human physiology course materials. Presented in this article, the author explores a puzzling method to engage BSN and BSES students as they increase allotted study group time to review textbook images and schematics while learning Nobel Prize-winning research (Anderson, 2018). This pedagogical approach creates a platform for undergraduate health professions students to improve awareness of ground-breaking research in medicine and physiology while studying textbook content.

WE NEED GAMES: The Inception of the "Puzzling Physiology and Nobel Laureates" Classroom Game

As previously noted, the structure of Marcella Niehoff School of Nursing Human Physiology for Health Professions lecture course at Loyola University includes face-to-face lectures with accompanying lecture notes and Panopto recordings accessible via a Sakai Learning Management System/ LMS course site (Apereo Foundation, 2018) that is free to enrollees, group sessions, practice assessments, trivia games, tactile physiology-pathophysiology models (Mahaffey, 2018), online games (Mahaffey, 2021), mnemonic devices (Mahaffey, 2022), augmented reality applications, and exam review sessions with complementary exam study guides (including relevant textbook topics, tables, figures, supplemental video URLs). The design of the study guide includes chapter sections topics, reference tables, videos resourced from textbook publisher and YouTube, and relative figures of pathways, anatomical depictions, and biological reactions. Since the introduction of the first course study guide in 2018 (to 2023), the author (and lecturer) noticed a study trend. This observed trend revealed student ranking of exam study guide materials as follows: Lecture Notes > Videos > Tables > Figures. The trend was identified through in-lecture student questions, emailed inquiries, and 1-on-1 meetings with enrollees. It became more apparent when the instructor would reference important figures from the exam study guide in-lecture and noticed a decline in student responses compared to references derived from lecture notes, videos, and tables. A parallel trend was established as exam questions on figure content had an observably lower response rate in comparison to the other three categories of study guide content. Whether this prioritization of review content was inadvertent or intentional remains to be evaluated. Another observation of this undergraduate health professions learning was an increase in student interest and response when the instructor would 1) introduce review materials via gamification and 2) parallel lecture content with modern-day discoveries and healthcare applications. The latter approach buoyed student awareness of scientific luminaries and their discoveries, while allowing enrollees to conceptualize human physiology outside of "classroom-thinking". Gamification is a teaching and learning approach that has been used in both STEM and nursing courses (Gómez-Urquiza et al., 2019; Taspinar et al., 2016), allowing students to review course concepts and utilize their critical thinking skillsets in an engaging platform. In the same vein, online game-based learning and information retrieval assignments have increased student interest for completing learning tasks and have aided in student retention of conceptual information (Anderson, 2018; Huang, 2011). Observations similar to these prompted the development of this "Puzzling Physiology & Nobel Laureates" game in the author's undergraduate health professions courses.

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Methods

Human Physiology Review Game: "Puzzling Physiology & Nobel Laureates"

Since 1901, the Nobel Prize has been a highly reputable and prestigious award bestowed upon researchers and members of society who have made groundbreaking and world-changing discoveries across multiple fields of research. To date, the prize includes a diploma, a gold medal engraved with the likeness of Alfred Nobel, and a monetary prize. The Nobel Prize is awarded to single, double, or triple recipients (nobelprize.org). The awardees provide a lecture and may attend a ceremonious banquet. Among the Nobel Prize award categories, are three (3) physical sciences: chemistry, physics, and physiology or medicine. Historically, there were approximately forty-nine times in which the awards ceremonies halted across all categories and these times occurred mostly during World War I (1914-1918) and World War II (1939-1945). The years in which the Nobel Prize ceremonies for physiology and medicine were suspended fall within the period of these world wars, as outlined at nobelprize.org: the years 1915, 1916, 1917, 1918, 1921, 1925, 1940, 1941, 1942. For the purposes of the "Puzzling Physiology & Nobel Laureates" game discussed, the focus of these methods will review Nobel laureate discoveries in physiology or medicine.

During this past spring semester, three rounds of "Puzzling Physiology & Nobel Laureates" game were played. Players require a laptop or iPad/tablet, access to the course textbook, and Wi-Fi. For each round, enrollees would apply depicted knowledge from textbook (and external) figures to solve for the correct Nobel Laureate name and their discovery. The selected topics corresponded with course learning outcomes, which further correlated with the American Physiological Society Core Concepts of Physiology Education (Table 1). Additionally, the Nobel Prize-winning discoveries aligned with physiology topics in upcoming exam chapters needing review from the instructor's perspective. For this semester, those focal chapters were glycolysis (more specifically Krebs cycle review), muscle physiology, and gastrointestinal (GI) system physiology (Figure 3, Q3). The resulting interactive learning goal was to promote student review of lecture and figure content within an engaged learning platform while increasing awareness of ground-breaking human physiology discoveries in medicine. The "Puzzling Physiology & Nobel Laureates" (PPNL)Mgame steps were as follows (Figure 1 for STEPS 1-5):

1. PUZZLES: Student participants were provided with an in-lecture PowerPoint slide presentation depicting several figures to decode the last name of the respective Nobel Laureate.

a. Given the likelihood of occurrence for common surnames, categories were provided to focus player searches in STEP 2. To elaborate, for the 1953 physiology or medicine prize awarded to H.A. Krebs for his discovery of the citric acid cycle in carbohydrates, the category was *"A Biochemical Process for ATP production"* (Figure 2). Another example is the 2005 prize in physiology and medicine to Robin Warren for his shared "discovery of the bacterium *Helicobacter pylori* and its role in gastritis and peptic ulcer disease" (Nobelprize.org), in which the PPNL segment was categorized as *"Tummy Ache"* and accompanied with an image of a pained stomach.

b. The PowerPoint slide contained a series of four image/figure depictions from the textbook (Stanfield, 2017) and external sources. Two images per row, with two rows of images on the slide. Participants review clues from left to right for each row in lecture with the option to take a photo for review outside of class (Figure 2).

c. Above each depiction was a clue. For example, "The FIRST two letters of the metabolic pathway depicted here." or "The FIFTH LETTER of the main product from the hypothalamus in the feedback pathway depicted below."

d. The resulting clues, with the prerequisite review of figures, revealed a LAST NAME.

2. DISCOVERIES: Following step 1, each participant would visit Nobelprize.org website, to search for the Physiology or Medicine Nobel Laureate of interest by last name that completed research in the highlighted category.

3. STUDENT GROUPS DISCUSSION: Students were permitted to work in groups of 2-4 to discuss figures as they attempted to solve each puzzle, initially during lecture with peers. Additional time was allotted for review outside of lecture with peers.

4. SOLUTION: Once the student has identified the likely Nobel laureate, they would log into Sakai LMS ("Tests & Quizzes" tab), and complete the 3-question Puzzle Solver Quiz (and submit). Although this was an optional exercise, additional participation points were provided to participants.

a. Name of Laureate

b. Year of Discovery

c. Description of Nobel Prize-winning discovery

5. IN-LECTURE REVIEW: Following submissions, a lecture presentation that includes a class discussion is used to draw connections between the highlighted Nobel Prize research, human physiology lecture content, and healthcare.

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Select Human Physiology for Health Professions Didactic/Laboratory Course Outcomes	**The Core Concepts of Physiology[a] (based on Michael- McFarland 2011 Rankings)**	**Puzzling Physiology & Nobel Laureates (PPNL) Game: Selected Nobel Laureates (Year of Award)[b]**
Upon completion of this course the student will be able to… **Describe the normal physiology of cells and tissues in the human body.**	*Cell membrane, Homeostasis, Cell-Cell communications, Interdependence, Flow down gradients, Energy, Structure/ Function, Physics/Chemistry, Genes to proteins, and Levels of organization.*	**A.V. Hill (1922)** *"for his discovery relating to the production of heat in the muscle"*
		H.A. Krebs (1953) *"for his discovery of the citric acid cycle"*
Examine the physiological interaction between organs and systems in the human body.	*Homeostasis, Cell-cell communications, Interdependence, Scientific Reasoning, Physics/Chemistry, Levels of Organization, and Mass balance.*	**A.V. Hill (1922)** *"for his discovery relating to the production of heat in the muscle"*
		H.A. Krebs (1953) *"for his discovery of the citric acid cycle"*
		J. R. Warren/B.J. Marshall (2005) *"for their discovery of the bacterium Helicobacter pylori and its role in gastritis and peptic ulcer disease"*
Explain the role of body systems and physiologic mechanisms in maintaining homeostasis.	*Cell membrane, Homeostasis, Cell-Cell communications, Interdependence, Flow down gradients, Energy, Structure/ Function, Scientific reasoning, Cell theory, Physics/Chemistry, Genes to proteins, Levels of organization, Mass balance, and Causality.*	**A.V. Hill (1922)** *"for his discovery relating to the production of heat in the muscle"*
		H.A. Krebs (1953) *"for his discovery of the citric acid cycle"*

[a] Core Concepts were adapted from those outlined by the American Physiological Society Center for Physiology Education, and as described by Michael and McFarland (Michael & McFarland, 2011) .
[b] Nobelprize.org

Table 1. *Comparison of Course Outcomes, APS CPE Core Concepts and PPNL Game Nobel Laureate Discoveries*

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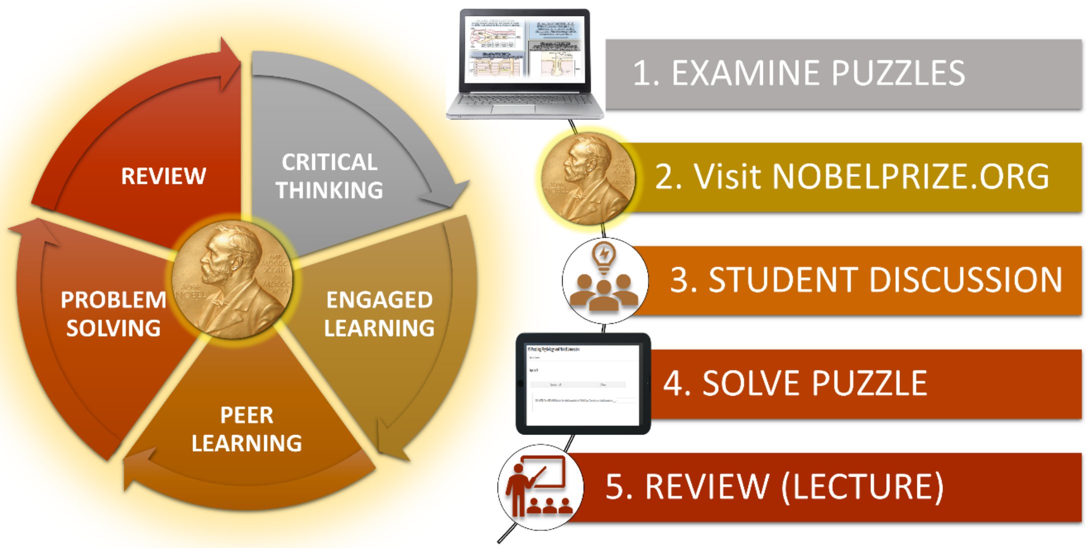

Figure 1. *Process and learning approaches for the "Puzzling Physiology & Nobel Laureates" Game.*

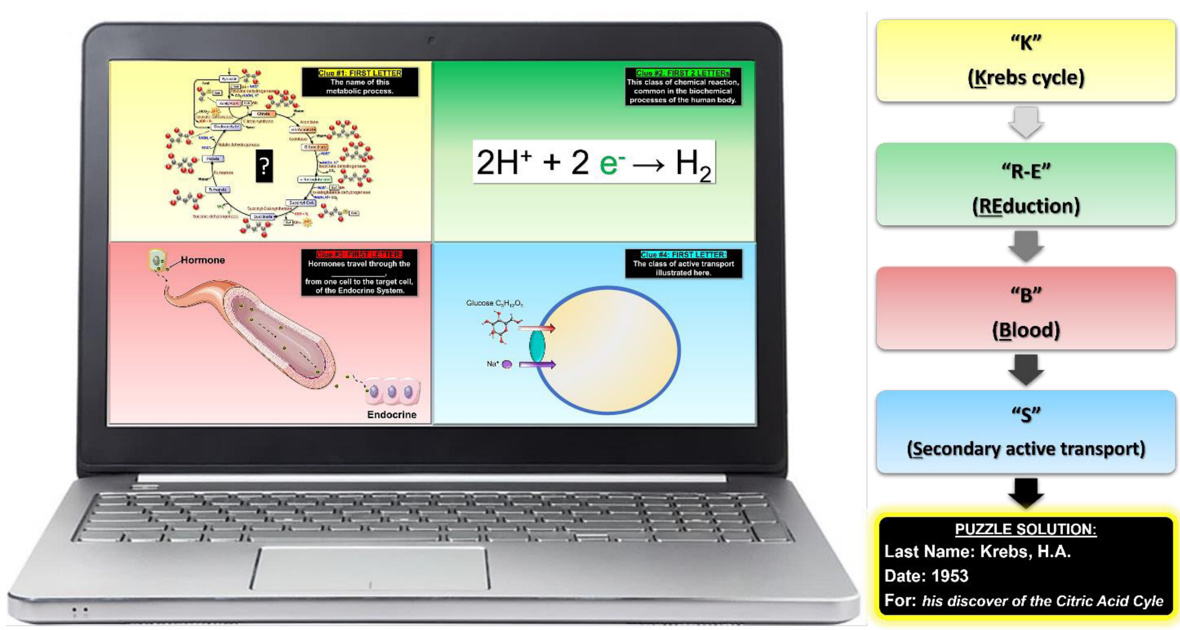

Figure 2. *A depiction of one of several "Puzzling Physiology & Nobel Laureates" Games (left) and the solution (right). This PPNL game segment includes clues for the 1953 Physiology or Medicine Nobel prize-winning discovery of the citric acid cycle by H.A. Krebs. Images were both created by the author and sourced from Wikimedia.*

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Development of a Qualitative Survey: An anonymous Qualtrics XM survey was formatted with security settings for one submission per person. The URL for the anonymous survey was shared in a group chatting app for the Spring 2023 Human Physiology for Health Professions course. A call for volunteers (including the link) was shared to the same app. Student anonymity was guaranteed via Qualtrics XM settings. Of the 148 enrollees in the Spring 2023 semester course, 117 opted to complete the Qualtrics XM online survey. The survey was a voluntary qualitative review of the "Puzzling Physiology and Nobel Laureates" game. Data from the survey was exported and analyzed. The anonymous survey results for the 117 student participants are discussed in the results section of this article. The results of the Qualtrics XM survey were divided into two parts: Part A) a review of BSES/BSN student responses to the selected Noble laureates and corresponding discoveries and Part B) a review of BSES/BSN student responses concerning the PPNL game in the undergraduate Human Physiology for Health Professions course. The Loyola University Chicago Health Sciences Division Institutional Review Board has exempted the qualitative analysis and data gathering of this physiology course's teaching and learning games and additional innovative approaches.

Results

Qualitative Survey: "Puzzling Physiology & Nobel Laureates" Game and Student Learning

Qualitative Survey PART A (Figure 3): Part A is a three-question series reviewing the PPNL game design. For this portion, 117 PPNL game participant responses were recorded. The first question assessed student-perceived difficulty in the PPNL game instructions, respondents were asked to select one of the five-point Likert-modelled measures: ranked from "Extremely Easy" to "Extremely Difficult" (Figure 3, Q1). More than 64% found the PPNL instructions as easy to follow with 19% as "Neither Easy/Difficult". As the PPNL five-step game instructions were presented during lecture, on a single PowerPoint slide, the survey results suggest that an improvement in the delivery of PPNL game instructions in future semesters may be helpful. The author theorizes that a single PowerPoint slide of game instructions may best serve participants if either provided in Sakai (versus in lecture) for each participant to review at their own pace; or dividing instructions into multiple PowerPoint slides (allowing for a one-step per slide presentation of instructions). The second question inquired about the three PPNL game categories used in this Spring semester: Cellular Metabolism (Krebs cycle), Muscular System, and Gastric System (Figure 3, Q2). Of the 117 participants, 52% selected all categories as most interested, having a disbursement of single responses for Krebs Cycle and Gastric System, with Muscular System edging out both choices. Lastly, for the Most Interesting Discovery, 115 participants responded with a wide range of selections (Figure 3, Q3). Here, the most interesting discovery was that of J. Robin Warren (2005), for his discovery of the role of H. *pylori* bacteria in peptic ulcers. This is intriguing as the "Gastric system" PPNL Game category was the least interesting (Figure 3, Q2). Students offered no explanation in the free response section of the survey to explain this curiosity. The qualitative results of both questions two and three (Figure 3, Q2 – Q3) display varied interests in the Nobel Prize-winning discoveries emphasized in this undergraduate health professions physiology game. On the success of the PPNL game, questions two and three reflect a catalyzation of student interest in physiology and medicine discoveries, which was an important goal in the PPNL game design.

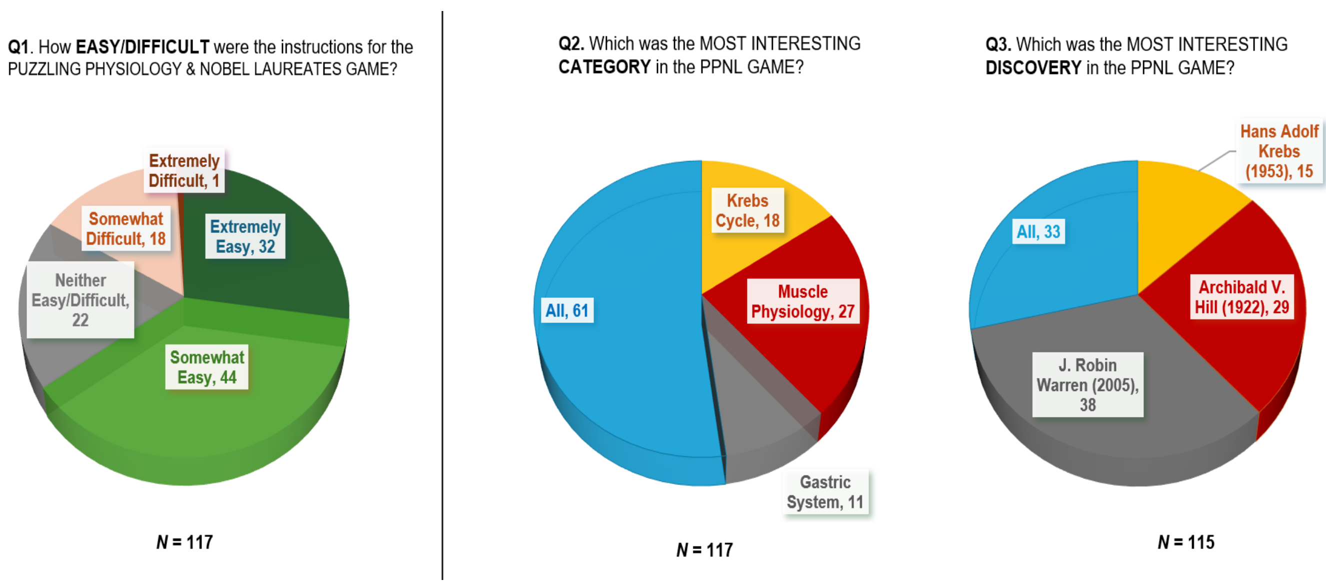

***Figure 3.** Qualitative (PART A) student responses to the "Puzzling Physiology & Nobel Laureates" (PPNL) Game in an Undergraduate Health Professions Course.*

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Qualitative Survey PART B (Figure 4): Part B of this anonymous PPNL game survey reviews the remaining six questions (Figure 4, Q4 – Q9), which discuss student recommendations and evaluation of the PPNL game and design. The five-point Likert scale for PART B evaluation ranged from "Strongly Agree" to "Strongly Disagree". Of the 117 respondents 96% would find it helpful if the PPNL game was available throughout the semester of human physiology (more than three times per semester) (Figure 4, Q4). Regarding the PPNL game being a "helpful" tool in reviewing relative chapter concepts and Nobel Prize-winning discoveries in Physiology and Medicine (Figure 4, Q5), 88% of the 117 participants agreed. Here, another goal of the PPNL game design was actualized, as student interest in medicine and physiology was a tenet of this gamified learning approach. In measuring student engagement, a question (Figure 4, Q6) on whether the PPNL was a "fun" exercise again showed that 88% agreed. Regarding students utilizing problem-solving and critical thinking skills, 95% and 96% respectively of participants agreed the PPNL game promoted the use of these skillsets (Figure 4, Q7 – Q8). On another positive note, of the 117 respondents 94% advocated for the continued offering of this PPNL game in the following semester human physiology for health professions courses (Figure 4, Q9).

A Comment on Cognitive Overload Mitigation and the PPNL GAME

Several indicators of cognitive overload include feelings of anxiety or stress in learning, being overwhelmed, difficulty applying critical thinking, problem-solving skills, and deductive reasoning during inquiry-based learning (Cezar, 2023). The qualitative data for the PPNL indicate, among other things, that the game was fun, allowed students to utilize critical thinking and problem solving with ease, and students would recommend continued implementation of the PPNL game in succeeding courses. There were no indicators from the data nor student comments for anxiety, a sense of being overwhelmed, difficulties focusing on problem-solving not stress in learning topics. The absence of cognitive overload indicators and positive student responses were indicative of overload mitigation and promotion of a positively effective learning exercise.

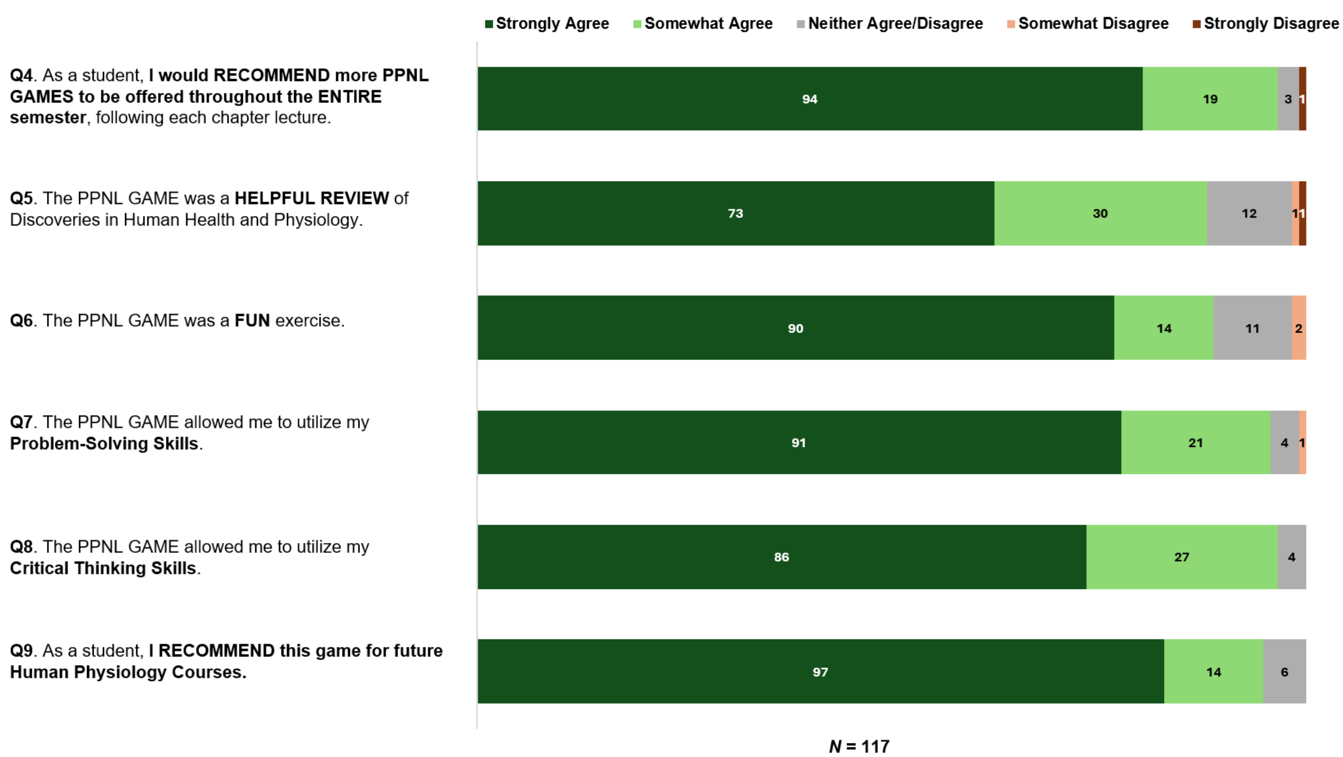

Figure 4. *Qualitative (PART B) student responses to the "Puzzling Physiology & Nobel Laureates" (PPNL) Game in an Undergraduate Health Professions Course.*

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Qualitative Survey on Nobel Prize Ceremonies and Physiology and Medicine

The author was interested in student awareness of the Nobel Prize ceremonies and more specifically their knowledge of physiology and medicine prize winners, preceding the PPNL game, so another qualitative survey was offered to participants via Qualtrics XM (Figure 5). Given that this anonymous and voluntary survey offering was during the final examinations period, 97 responses for this three-part and three to five-point Likert-type survey were collected. Q1 of the survey inquired if participants had an underlying awareness of the Nobel Prize prior to the PPNL game, in which 55% of respondents gave a reported "yes". As a note, the result may underscore an opportunity for more Nobel Prize-winning discoveries to be discussed in high school or undergraduate STEM and health textbooks because most respondents are first-year undergraduate students. The second survey question asked whether respondents were aware of the Nobel Prize specifically offered for physiology and medicine discoveries before participating in the Spring semester game. Only 21% of these respondents voted in the affirmative (Figure 5). Once more, the author stresses the need for incorporating more Nobel Prize-winning discoveries in STEM (and health) textbook materials, especially for future health professionals and physical scientists - as these discoveries are often the foundation of STEM and health sciences education. Lastly (Figure 5, Q3), when asked of their likelihood of watching the upcoming Nobel Prize announcements after completing the PPNL game, students responded using a five-point Likert-modelled scale of "Very Likely" to "Not at All" and nearly 82% indicated a likelihood to stay apprised of the Nobel Prize in Physiology and Medicine announcement of winners. The results underline the efforts of the PPNL game to buoy student awareness of up-to-date physiology or medicine discoveries and interest in the Nobel Prize awards.

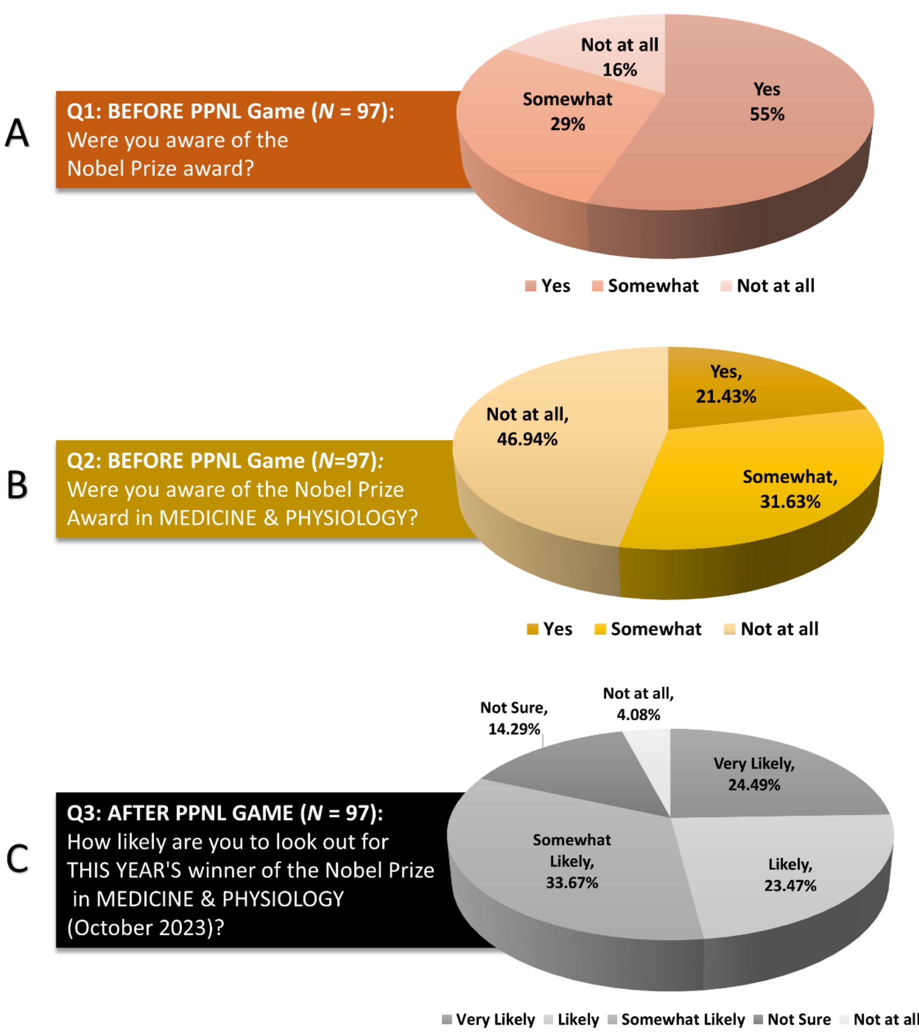

Figure 5. *Post "Puzzling Physiology & Nobel Laureates" Game qualitative student participant survey results on the Nobel Prize ceremonies.*

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Conclusion

The aim of the PPNL game was to offer a series of engaging assignments for BSES and BSN students enrolled in an undergraduate Spring semester human physiology course for health professions. The platform gamified the textbook figures in an effort to promote student review of course materials and enhanced awareness of Nobel Prize-winning discoveries in physiology or medicine. Post-game qualitative research highlights the engagement and critical thinking aspects of this online game assessment. Given the results discussed, a plan is to incorporate more Nobel Prize discoveries into a larger scale "Puzzling Physiology and Nobel Laureates" game (i.e., offering more than three categories of matching course topics with physiology and medicine discoveries) for succeeding courses of human physiology for health professions.

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Author Contributions

A.L.M. conceived and designed research; performed experiments; analyzed data; interpreted results of experiments; prepared table; drafted manuscript; edited and revised manuscript; and approved final version of manuscript.

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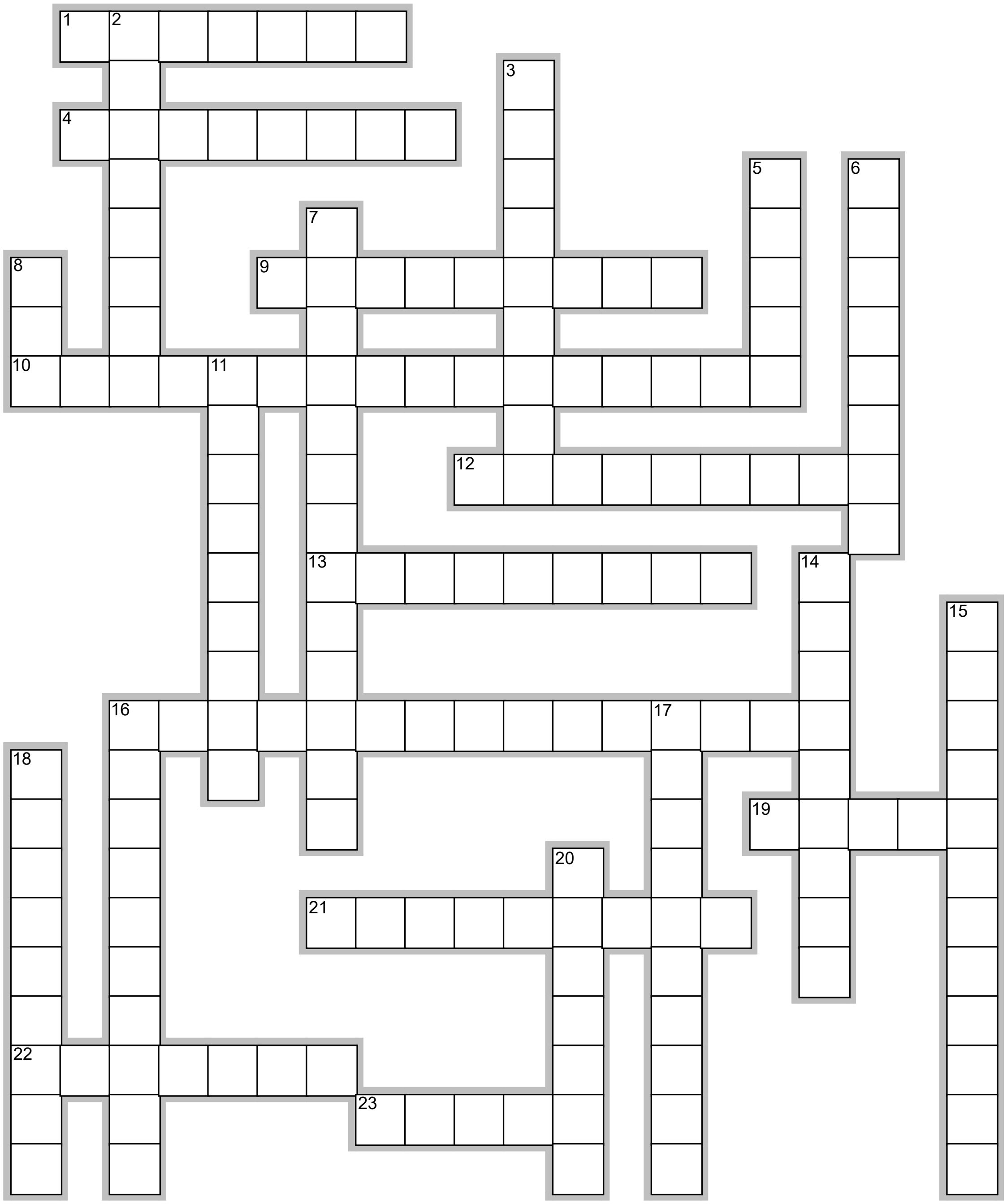
HAPS Educator Crossword 1: Histology (For an online version CLICK HERE.)



ACROSS

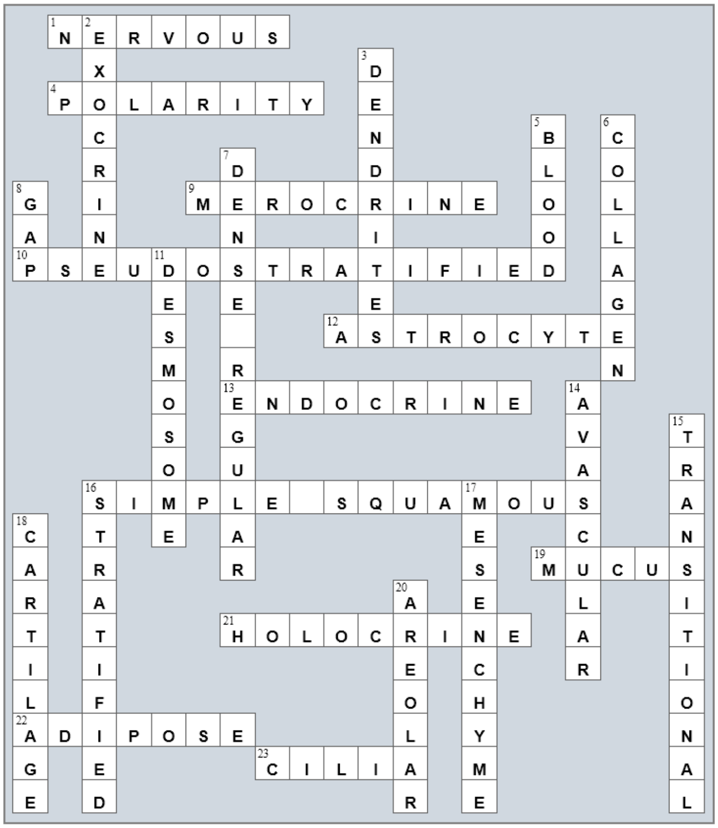
1. Primary tissue type that is involved in communication and regulation.
4. Property of epithelia: they have an apical surface and a basal surface
9. Most common type of exocrine glandular secretion.
10. Describes a type of epithelium that appears to be multi-layered, but isn't.
12. Most common type of glial cell that anchors neurons close to capillaries.
13. Type of gland that can release its product into the bloodstream.
16. Epithelium that provides as the thinnest barrier (2 words; space in between).
19. Product released by goblet cells.
21. Type of glandular secretion in which whole cell ruptures when releasing product.
22. Type of connective tissue that stores fats.
23. Hair-like processes on the apical surface of columnar epithelia lining the trachea.

CLICK HERE for Answer Key

DOWN

2. Type of gland that uses ducts to convey its product to its destination.
3. Branching cellular extensions at the receiving end of a neuron.
5. Fluid connective tissue.
6. Type of fiber that gives connective tissue its strength.
7. Type of connective tissue that composes tendons (2 words; space in between)
8. ________ junctions allow ions to move directly from one cell into its neighbor.
11. Type of cell-cell junction that is strong and connected to the cytoskeleton.
14. Term for absence of blood vessels running through epithelial tissues.
15. Type of epithelium that lines the bladder because it fills and empties.
16. Describes a type of epithelium that is multi-layered.
17. Name for embryonic connective tissue.
18. Type of connective tissue that contains chondrocytes.
20. Connective tissue often responsible for tissue edema.

Answer key for:
Crossword 1. Histology
(from page 65)



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HAPS COMMITTEES AND BOARDS

Standing Committees:

2024 ANNUAL HOST

Cinnamon VanPutte

This committee is in charge of coordinating the 2024 Annual Conference to take place in Pittsburgh, Pennsylvania

ANATOMICAL DONOR STEWARDSHIP

Kelsey Stevens

This committee is charged with developing, reviewing, and recommending policies and position statements on the use of cadavers for human anatomy and physiology education in colleges, universities and related institutions.

AWARDS & SCHOLARSHIPS

Chasity O'Malley

This committee administers the application process and selects the recipients of all of the HAPS grants and scholarships.

COMMUNICATION

Caitlin Burns

This committee is tasked with helping HAPS establish its voice in a technological landscape shaped by social media. Committee members work closely with the Marketing Committee to facilitate connections within HAPS as well as recruiting potential members via social media.

CONFERENCES

Edgar Meyer

This committee actively encourages HAPS members to consider hosting an Annual Conference. We provide advice and assistance to members who are considering hosting an annual conference.

CURRICULUM & INSTRUCTION

Abbey Breckling

This committee develops and catalogs resources that aid in anatomy and physiology course development and instruction.

DIVERSITY, EQUITY, AND INCLUSION

Juanita Jellyman

The purposes of this committee are to develop best practices, resources, and professional development opportunities for inclusive education in anatomy and physiology, and to advocate for and ensure inclusive practices within the organization and at HAPS events.

FUNDRAISING

Stacey Dunham

This committee organizes fundraising activities to provide funding to support HAPS awards and to support HAPS members working on a variety of new initiatives.

STEERING

Larry Young

This committee consists of all committee chairs. It coordinates activities among committees and represents the collective committee activity to the HAPS BOD.

Click here to visit the HAPS committees webpage.

Special Committees and Programs:

HAPS EDUCATOR

Jackie Carnegie, Editor-in-Chief

Brenda del Moral, Managing Editor

This committee is responsible for publishing editions (3-4 annually) of the *HAPS Educator Journal of the Human Anatomy and Physiology Society*

EXAM PROGRAM LEADS

Valerie O'Loughlin

Dee Silverthorn

Janet Casagrand

This committee has completed, tested and approved the HAPS Comprehensive Exam for Human A&P and is developing an on-line version of the exam.

EXECUTIVE

Kerry Hull

Composed of the HAPS President, President-Elect, Past President, Treasurer and Secretary

FINANCES

Ron Gerrits

This committee tracks the various sources of income and expenditures of HAPS to ensure that the organization stays in a strong fiscal position while continuing to support the HAPS membership via regional and annual conferences and can continue to provide resources that support members throughout their career development as educators of human anatomy and physiology.

NOMINATING

Melissa Quinn

This committee recruits nominees for HAPS elected offices.

PRESIDENTS EMERITI ADVISORY

Kyla Ross

This committee consists of an experienced advisory group including all Past Presidents of HAPS. The committee advises and adds a sense of HAPS history to the deliberations of the BOD

WELCOMING AND BELONGING

Melissa Quinn

Larry Young

This committee is dedicated to fostering an inclusive and welcoming environment where every member feels valued, respected, and empowered to find their level of participation and professional growth. The committee actively words toward expanding HAPS's reach and impact by attracting new members and supporting current members reflecting the diversity of the faculty, students and institutions across our discipline.

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