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CourseSource

Lesson

Teaching Cell Structures through Games

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Abstract

As the basic unit of life, cells are a foundational concept for all of biology. Before students can appreciate how eukaryotic cells function either in isolation or in higher order and multicellular organisms, they must first have a basic understanding of the organelles that make up these cells. The primary objective of this lesson is to provide a fun and engaging way for students to learn the function and arrangement of eukaryotic organelles. This lesson uses familiar and easy to learn games – Pictionary® and Bingo – to help students enrolled in introductory, non-majors biology courses better recognize cellular organelles and understand their functions.

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Supporting Materials: S1. Cell Structure Games - Reading Guide; S2. Cell Structure Games - Game Cards; S3. Cell Structure Games - Cell Bingo Boards; S4. Cell Structure Games - Definitions Page; S5. Cell Structure Games - Cell Structure Quiz 1; S6. Cell Structure Games - Cell Structure Quiz 2; S7. Cell Structure Games - Cell Structure Quiz 1 Answer Key; S8. Cell Structure Games - Cell Structure Quiz 2 Answer Key; and S9. Cell Structure Games - Exam Questions.

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Learning Goal(s)

Students will:

- understand the structures of prokaryotic and eukaryotic cells, including their similarities and differences.
- know the arrangement and function of eukaryotic organelles and structures

Learning Objective(s)

Students will:

- identify cell structures when viewing an image or diagram of a cell.
- define the function of eukaryotic organelles and structures, including describing the processes and conditions related to transmembrane transport
- differentiate between prokaryotic and eukaryotic cells, plant and

INTRODUCTION

Students entering college have usually had extensive exposure to the foundational concepts of eukaryotic cell structure, such as organelle names, locations, and functions. In Alabama, students are first introduced to cell structure in the seventh grade and gain continued and deepened exposure through subsequent science courses, including a required high school biology class.

It has been my experience, however, that students do not remember these basic concepts when they reach the undergraduate biology classroom. Of the students who do, their memory most often consists of a series of commonly taught analogies such as "the nucleus is the brain of the cell" or "the mitochondrion is the powerhouse of the cell." When I press students to explain the meaning of these analogies, they cannot, which demonstrates rote memorization rather than authentic understanding on the part of the students. However, students need to have a firm grasp of cell structure and the roles of organelles in proper cell function before we can expect them to grapple with more complex concepts like the specialization of cells within tissues or diseases caused by cellular dysfunction.

I and others have published a variety of approaches for teaching cell structure in undergraduate introductory biology courses. However, most of these techniques are intended to promote a higher order of understanding and assume that students have already mastered the basic concepts. For example, both "The Cell: An Image Library" and "Cell Engineer/Detective" aim to help students make a connection between cell structure and cell function but expect students to enter the activities with an existing understanding of organelle identity and function (1,2). Methods that do aim to help students gain the more basic knowledge either involve traditional lecture, which is largely ineffective, or are time consuming. For example, Lazarowitz and Naim describe an approach using three-dimensional modeling, but the activity requires multiple class and lab periods over the span of several weeks to complete (3). This kind of timeline is just not conducive to a non-majors survey course.

My goal in designing the lesson presented here was to fill in the gaps outlined above - to design an activity that teaches the foundational concepts of cell structure to undergraduate biology students in a way that is engaging and can feasibly be completed within a single class period. In order to achieve this goal, I adapted two common and easy to learn games - Pictionary® portion of this lesson. and Bingo - to feature the terminology and models of eukaryotic cell structures.

Educational games are particularly effective for engaging and motivating students, creating a positive classroom environment, and improving overall student performance (4). Science instructors have developed games to teach everything from the process of science to aerobic respiration and action potentials (5-7). In terms of teaching students the basics of cell structure, I found games particularly appealing because they can engage a large group of students with a wide range of competencies. Since students enter introductory biology courses with varying levels of knowledge about cell structures, games are a way to keep more advanced students from becoming bored while helping bring less prepared students up to speed. Also, because Pictionary® and Bingo are fairly well known and relatively easy to learn, I do not have to spend a large amount of class time teaching students how to play, helping the activity fit within the time period allotted.

Intended Audience

I designed this lesson for undergraduate introductory biology courses. I initially developed and tested the activities at my small public liberal arts institution in my Principles of Biology course, which is a class of 30 predominantly non-science majors. However, this lesson has also been used as a review activity for other biology courses, including an introductory biology course for science majors and a junior level cell biology course.

Required Learning Time

As written and developed, this lesson can be completed in a 75 minute class period, with 30 minutes to play Cell Pictionary® , 20 minutes to play Cell Bingo, and 25 minutes for transitions and an exit quiz. However, these times can be easily adjusted to fit a variety of timelines.

Prerequisite Student Knowledge

Students should have basic knowledge of the shapes, structures, and functions of common eukaryotic cell organelles.

Prerequisite Teacher Knowledge

Instructors should have basic knowledge of the shapes, structures, and functions of common eukaryotic cell organelles.

SCIENTIFIC TEACHING THEMES

Active learning

This lesson uses game-based learning as an active learning strategy to reinforce concepts of eukaryotic cell structure and function. Students engage with the material during the Pictionary® -style game by drawing organelles or basic cell processes for their teammates to guess. Students who are guessing during this portion of the game are required to visualize what is being drawn in order to determine the identity. During the Bingo-style game, students must connect the definitions or functions of cell structures or processes with the terms that are present on their game cards.

Assessment

Students were casually assessed during the lesson by tracking performance during the games. For formative assessment of the learning objectives, students completed a low-stakes quiz immediately after the lesson was completed. For summative assessment of the learning objectives, students answered a collection of questions related to cell structure and function on an exam that was administered 2 weeks after the lesson was completed. Qualitative feedback was also collected through informal discussions with the students after completion of the activity.

Inclusive teaching

By adapting games that are broadly familiar, this lesson provides students with a common framework around which they can construct their learning and places students on a more equal level from the outset. Additionally, the familiarity provides a personal relevance that has been shown to improve learning irrespective of student background (8). However, not all students may be familiar with these games, particularly international students. These games tend to be easy to learn and working in teams can accelerate the learning process. Teams are also useful for helping instructors maximize diversity by populating the teams with students from different backgrounds. Furthermore, the team-based and multimodal approaches of this lesson allow students to leverage the diversity within their teams as they play the games, i.e. artistic students can be responsible for drawing during Cell Pictionary® if they so choose.

LESSON PLAN

Pre-Class Preparation

For students

A few days prior to the activity, instruct students to read about cell structure and function while answering the Reading Guide questions (Supporting File S1: Cell Structure Games - Reading Guide). My students read Chapter 3: Cell Structure and Function in the open textbook Concepts of Biology (9). Before completing the activity, students should be able to define the following terms: cell wall, chloroplast, cilia, cytoplasm, cytoskeleton, endoplasmic reticulum, flagella, Golgi apparatus, lysosome, mitochondria, nucleus, peroxisome, plasma membrane, ribosome, vesicle, vacuole, active transport, endocytosis, exocytosis, facilitated diffusion, osmosis, passive diffusion, hypotonic, hypertonic, and isotonic.

For the instructor

Print the Game Cards (Supporting File S2: Cell Structure Games - Game Cards) and cut them out. These cards will be used for both Cell Pictionary® and Cell Bingo. I printed on card stock so that the cards would be more durable and could be used for multiple games. You will want to fold the cards so that the terms on the cards are not visible and place all of the cards in a bowl or basket.

Print the Cell Bingo Boards (Supporting File S3: Cell Structure Games - Cell Bingo Boards). The file contains 10 distinct play cards. I printed the boards on card stock and laminated them in order to allow the students to mark off squares during the game using dry erase markers. This way mistakes could easily be erased and the boards could be reused.

Print the Definitions Page (Supporting File S4: Cell Structure Games - Definitions Page). These definitions are adapted from Concepts of Biology (9), but can be modified to mirror definitions from the textbook adopted for your particular class. I placed this sheet inside of a sheet protector, so that I could

use a dry erase marker to mark off terms as they are used during the Cell Bingo.

In-Class

Assigning teams

When students arrive in class, divide them evenly into teams. The size of the teams and how they are selected depends largely on class size and instructor preference. I divided my students into groups of three, as this would allow for one student to draw during Cell Pictionary® while the two remaining students on a team could support one another in identifying what was being drawn.

Before beginning the game, give teams a few minutes to introduce themselves to one another. I also encouraged my students to come up with a team name, which they wrote on a placard placed in front of them. This allowed me to easily keep track of points during the games.

Learning activity #1: Cell Pictionary®

Before beginning the game, determine the order in which teams will play. Each team will have one minute to play during their turn. It is helpful to have a player not on the drawing team serve as time keeper. Teams should select one member to serve as the artist for the team. This role can rotate between players if the team so chooses but only on subsequent turns.

The first team's artist comes to the front of the classroom. S/he selects a Game Card (Supporting File S2: Cell Structure Games - Game Cards) from the basket and looks at it. After the card is viewed, start the one minute timer. The artist draws the structure or a diagram of the process corresponding to the term on the Game Card on the classroom board for the class to see. The artist's team members try to guess the term based on the drawing. The artist cannot speak or motion to the team members or use words or numbers in his/her drawing. If the team members guess the term before the one minute is up, the artist can select another Game Card and repeat the process. This continues until the timer sounds. The team receives one point for every term that is correctly guessed.

If the team has not correctly guessed the term when the timer sounds, allow other teams to guess. If another team is able to correctly name the term, award that team a point.

Before play moves to the next team, discuss the term(s) from the round of play with the class. Ask students to define the term or you can provide the definition from the Definitions Page (Supporting File S4: Cell Structure Games - Definitions Page). You may also direct students to view an appropriate diagram depicting the term in the course textbook.

Move to the next team and repeat the procedure, again allowing one minute for play. Play can continue as long as time permits. In my class, each of the 10 teams was able to play twice during the 30 minutes that I allotted for the activity.

Transition between learning activities

As a transition between learning activities, summarize what the students just did and why, then offer a preview of what you will be doing next. It is also helpful to provide students with a score update during this transition if you are not displaying the scores on the board, as competition enhances engagement (10).

To summarize the Cell Pictionary® game, explain to the students that being able to visualize the features of a cell as was required in the game is important for a variety of reasons. Specifically, the location of organelles within a cell is often related to that organelle's function. For example, the endoplasmic reticulum, responsible for modifying proteins, will send proteins to the Golgi apparatus after modification so that they may be sorted and sent to their final destinations within the cell. Because of the links in function between these organelles, they are typically located in close proximity to one another within the cell. Alternatively, cell function and/or dysfunction is often reflected in cell structure. For example, cells with a high energy requirement like muscle cells will have significantly more mitochondria in their cytoplasm in order to supply cells with the adequate amount of ATP. Therefore, being able to recognize cell structures will aid in understanding cell and/or organelle (dys)function.

To preview the Cell Bingo game, explain to students that understanding the function of cellular organelles is also important. In order for students to perform well in Cell Bingo, they will need to be able to match a verbal description of a term's definition with the proper term.

Learning activity #2: Cell Bingo

Distribute a Cell Bingo Board (Supporting File S3: Cell Structure Games - Cell Bingo Boards) and dry erase marker to each team. Re-fold and return all of the Game Cards to the basket and mix the cards well.

Explain the rules to the students. You (the instructor) will draw a card from the basket. Rather than read the term on the card, you will read the definition of the term. Students will then work as a team to identify the term and determine whether it is present on their team's Cell Bingo Board - not all terms are present on all boards. To win the game, a team needs to get four terms in a row vertically, horizontally, or diagonally. Each board also contains a free space that can be used in place of one of the four terms in a row.

Begin play by drawing your first Game Card from the basket. Read the definition from the Definition Page. Mark the term on the Definition Page to help you quickly identify which terms have been called. Continue drawing cards and reading definitions until the first team calls Cell Bingo. Have that team list the four terms of their Bingo and provide definitions. Check to make sure the terms and definitions are accurate. If they are not, correct the mistakes and continue play until the next team calls Bingo. If the terms and definitions are accurate, the team wins the round and is awarded four points.

Have all teams erase their Cell Bingo Boards with a paper towel or rag and begin play again. Play can continue as long as time permits. In my class, we were able to complete two full rounds of Cell Bingo in the 20 minutes that I allotted for the activity.

Post-Activity Summary and Assessment

After conclusion of the Cell Bingo game, use a few minutes to again summarize the importance of being able to recognize

cell structures and to define their functions within the cell. In order to assess the student learning outcomes for this activity, have students complete one of the Cell Structure Quizzes (Supporting Files S5: Cell Structure Games - Cell Structure Quiz 1 and S6: Cell Structure Games - Cell Structure Quiz 2). These quizzes require students to identify organelles in a eukaryotic cell and to define the functions of the organelles. After students have completed the quiz, use the Answer Keys (Supporting Files S7: Cell Structure Games - Cell Structure Quiz 1 Answer Key and S8: Cell Structure Games - Cell Structure Quiz 2 Answer Key) to review the answers and answer any questions that the students have.

Conclude the class by posing a thought-provoking question to open the door for a future discussion of cellular function/dysfunction. For example, you can explain to students that not all cells within the body look and function the same way, then ask the students to consider how the structure of a cell responsible for muscle contraction may differ from the structure of a cell responsible for protein production and secretion. Such a line of questioning would provide an excellent transition into the previously published lesson, Cell Engineer/Detective, an active learning approach designed to illustrate the direct link between cell structures and their function (2).

TEACHING DISCUSSION

Effectiveness for Achieving Student Learning Outcomes

This Lesson was developed and piloted in a single section of BIO 100 Principles of Biology during the fall 2018 semester. Students completed one of the Cell Structure Quizzes (Supporting Document S5: Cell Structure Games - Cell Structure Quiz 1) at the beginning of the class period, after having read the assigned material but before beginning the lesson. Students then completed the second Cell Structure Quiz (Supporting Document S6: Cell Structure Games - Cell Structure Quiz 2) after completing the lesson. Neither of the quizzes' answers were discussed until after completion of the second quiz. As shown in Figure 1, the average quiz score rose from 53% correct on the pre-lesson quiz to 60% correct on the post-lesson quiz. While not statistically supported, the data suggested that student understanding of cell structure was greater after the activity than before.

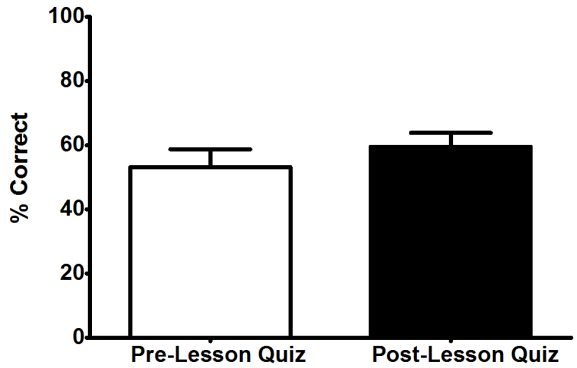

Figure 1. Average scores on the Cell Structure Quiz completed after the lesson were higher than scores on the Cell Structure Quiz completed before the lesson.

Student learning was also assessed two weeks after the lesson on a semester exam. The exam contained ten multiple choice questions that were directly related to the goals of this lesson (Supporting Document S9: Cell Structure Games - Exam Questions). The average percentage of correct answers on these questions was 82% as shown for the experimental group in Figure 2. Comparable questions have been included on exams in six sections of the course that I have taught previously using a more traditional lecture approach. Data from these sections were pooled. As shown for the control group in Figure 2, the average percentage of correct answers in previous semesters was 73%, which was significantly lower than when the cell structures were taught using games. These data support the use of these activities over traditional lecture to promote student learning.

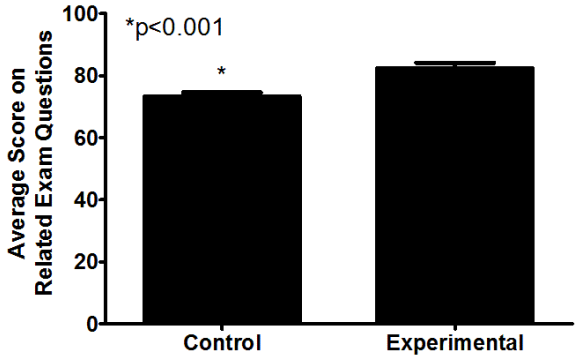

Figure 2. Average performance on exam questions related to learning goals increased in the section of the course using these activities (experimental group, white bar) compared to sections of the course taught with traditional lecture (control group, black bar). The p value was calculated using student's t test comparing pooled control group data to the experimental group.

In addition to these quantitative measures, qualitative feedback was received by asking students about their perceptions of the activity. All of the students agreed that the games were more engaging than a traditional lecture, and most of the students believed that the games improved their understanding of cell structures. One student commented, "I thought I knew what all of these parts were, but I froze when I had to draw them. I guess I didn't know them like I thought I did." When the game was used as a review for my junior level cell biology class, the students did not want to stop playing and requested to borrow the materials to use during an informal study session after class. One student remarked, "I rolled my eyes when you said we were going to play a game. I was surprised that it was actually fun."

Adaptations

You may wish to consider administering one of the Cell Structure Quizzes (Supporting Documents S5: Cell Structure Games - Cell Structure Quiz 1 and S6: Cell Structure Games - Cell Structure Quiz 2) before the class period in which the lesson will be performed. Doing so will help you and the students gauge their understanding of cell structure and function prior to beginning the lesson.

While this lesson was developed in a class with 30 students, I believe that it could easily be scaled for larger class sizes. Teams could be enlarged from three to as many as five players, accommodating up to 50 students. Teams with more than five players will likely be limited in the amount of meaningful interaction between teammates during game play and find it difficult for all players to see the Cell Bingo Board. In the right venue, classes larger than 50 students could be divided into two separate sets of teams and the games could be played

in parallel, although this may require the support of teaching assistants.

While competition alone has been shown to increase student engagement (3), offering some sort of reward for winning teams may further promote student engagement and buy-in. During the pilot, I awarded members of the first place team exam bonus points. The students in my class knew that this was at stake before beginning the lesson.

It was also noted that some terms, particularly the processes and conditions (i.e. endocytosis, hypertonic) were more difficult for students to draw during the Cell Pictionary® portion of the game. It might be helpful to keep those terms out of play at the beginning of the game and to add them in after the first round of play. Doing so may allow students some time to warm up and orient themselves to the rules of the game.

SUPPORTING MATERIALS

- S1. Cell Structure Games - Reading Guide. Provides a framework to guide students' reading to prepare them for completing the in-class portion of this lesson.
- S2. Cell Structure Games - Game Cards. Contains the terms divided onto game cards that will be folded and placed in a basket for use during both Cell Pictionary® and Cell Bingo.
- S3. Cell Structure Games - Cell Bingo Boards. Contains 10 unique game boards for use during Cell Bingo.
- S4. Cell Structure Games - Definitions Page. Contains the definition for the terms present on the Game Cards to be used during both Cell Pictionary® and Cell Bingo.
- S5. Cell Structure Games - Cell Structure Quiz 1. Contains a quiz that can be used to assess the student learning outcomes of the lesson.
- S6. Cell Structure Games - Cell Structure Quiz 2. Contains an alternative quiz that can be used to assess the student learning outcomes of the lesson.
- S7. Cell Structure Games - Cell Structure Quiz 1 Answer Key. Contains the answers to the Cell Structure Quiz 1 (Supporting Document S5).
- S8. Cell Structure Games - Cell Structure Quiz 2 Answer Key. Contains the answers to the Cell Structure Quiz 2 (Supporting Document S6).
- S9. Cell Structure Games - Exam Questions. Contains 10 multiple choice questions that can be used to assess the student learning outcomes of the lesson. Correct answers are indicated by an asterisk (*) next to the letter choice.

ACKNOWLEDGMENTS

I would like to acknowledge all of the students in my section of Principles of Biology at the University of Montevallo who participated in the pilot of this lesson. I would also like to thank the University of Montevallo students who were not involved in the pilot of this lesson but volunteered to be photographed playing the game for this article.

Pictionary® is trademarked and manufactured by Hasbro/ Milton Bradley.

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Table 1. Cell Structure Games - Teaching Timeline

Activity	Description	Time	Notes
Preparation for Class			
Assign students reading about cell structures	1. Instruct students to read about eukaryotic cell structure and function in their textbook. 2. Provide students with guiding questions to prepare them for the activity.	About 1 hour	Reading Guide is provided in Supporting File S1.
Prepare game materials for use in class	1. Print one set of Game Cards, cut them out, fold them, and put them in a basket. 2. Print one Bingo Board for each student group. 3. Print the Definitions Page. 4. Gather one dry erase marker for each student group.	About 15 minutes	• Game Cards are provided in Supporting File S2. • Bingo Boards are provided in Supporting File S3. • Definitions Page is provided in Supporting File S4. • Print the Game Cards and Bingo Boards on card stock to make them more durable. • Laminate the Bingo Cards for use with dry erase markers. • Place Definitions Page in sheet protector for use with dry erase markers.
During Class			
Assign students to teams	Students should be assigned or self-select into teams of 3-5 students.	~5 minutes	
Cell Pictionary®	Student teams will take turn drawing and guessing terms	~30 minutes	Between teams review the meaning of terms from the previous round of play.
Transition	Summarize main points from Cell Pictionary® and transition to Cell Bingo	~5 minutes	Give a score summary to encourage continue engagement.
Cell Bingo	Student teams identify terms on their Bingo Boards in response to definitions read by instructor	~20 minutes	
Assessment	Individually students complete a quiz to evaluate learning.	~15 minutes	• Two versions of Cell Structure Quizzes are provided in Supporting Files S5 and S6 with answer keys in Supporting Files S7 and S8. • Multiple choice exam questions assessing student learning outcomes are provided in Supporting File S9.