An Original-Design Board Game to Increase Student Comprehension of Cellular Respiration Pathways

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Abstract

Cellular respiration is a daunting topic for many students in introductory biology courses. Students are challenged at conceptual and factual levels, since instruction covers multiple metabolic pathways occurring across different cellular compartments, involving abstract energy and electron transfers through diverse chemical reactions. Lecture-based instruction may clearly convey details of cellular respiration to students, but the complexity of this topic suggests alternative, active learning strategies may improve student comprehension and retention. I designed an original board game as a teaching tool for cellular respiration, targeted at improving learning outcomes for advanced high school, introductory undergraduate, and upper-level undergraduate biology students. “Aerobic Respiration: The Board Game” applies multiple learning strategies (quiz questions, student-completed study table, visual, tactile and quantitative learning, and game-play) with the goal that students are simultaneously entertained and invested in understanding this complex topic. Initial application in a small undergraduate introductory biology section (ca. 25–30 students) suggested improved student understanding of some aspects of cellular respiration. Use in a longer class or lab period and simplification of game board design and instructions should improve effectiveness of the game. Students had significantly favorable perceptions of the game as a learning tool. Included game board and game cards are provided to reflect multiple student academic levels, and are fully editable. Ordering information for materials and game pieces is also included.

Learning Goals

Students will improve their understanding of:

◊ chemical reactions of glycolysis, pyruvate oxidation, the Krebs cycle, electron transport/oxidative phosphorylation, and fermentation, including pathway inputs and outputs.
◊ energy and electron transfers associated with glycolysis, pyruvate oxidation, the Krebs cycle, electron transport/oxidative phosphorylation, and fermentation.
◊ role of NAD and FAD as electron carriers in aerobic respiration and fermentation.
◊ role of fermentation in regenerating oxidized NAD in the absence of oxygen.
◊ experimental design and the scientific process.

The above Lesson Learning Goals align with the following society-generated learning goals:

◊ From Biochemistry and Molecular Biology Learning Framework:
  » What is the nature of biological energy?
  » How is energy of chemical processes coupled in metabolic pathways?
◊ From Cell Biology Learning Framework:
  » How do solutes and other materials move across membranes?
  » How do cells transform energy and cycle matter?

Learning Objectives

◊ During the course of game play, students will complete a provided study guide review sheet covering critical details of cellular respiration.
◊ Students will improve and assess their own understanding of cellular respiration pathways, including pathway inputs and outputs.
◊ Students will improve and assess their own understanding of energy and electron flow through the pathways of cellular respiration.
INTRODUCTION

Cellular respiration is traditionally a challenging topic for science students at all levels, and is particularly challenging for first- and second-year undergraduate students (1). As a topic, cellular respiration typically includes five metabolic pathways (glycolysis, pyruvate oxidation, the Krebs cycle, electron transport/oxydative phosphorylation, and fermentation), occurring across three cellular compartments (cytoplasm, mitochondrial matrix and intermembrane space), and involving electron and energy transfers, and chemical rearrangements, across many chemical reactions. The complex nature of this topic supports that students may gain a fuller understanding of cellular respiration processes via active learning strategies, as opposed to solely lecture-based formats.

The phrase ‘serious games’ refers to games designed with a primary purpose other than strictly entertainment. Traditionally this phrase is used to refer to digital (video) games used for education and training; however, serious games have a longer and more diverse history including board game formats (2). Implementation of game-based learning in the science classroom has been shown to improve student academic performance and even student behavior (3, 4). In biology, digital and non-digital serious games have been applied in gamified active learning environments, including quiz-based digital formats like ‘KAHoot!’ (5), augmented reality (6), and board games (7, 8). One commercially available board game, Mouse Trap™ (Hasbro, Milton Bradley), has also been adapted specifically for teaching pathways of cellular respiration (9). While digital and online game formats have great potential as teaching tools in science, they also present persistent challenges, including difficulty in coding and design, portability and cost, and potentially reliance on high-speed internet connections. Alternatively, non-digital gaming formats, for example card and board games, typically have more tractable design and represent both economical and easily portable teaching tools. One potential drawback of both digital and traditional gaming formats is a lack of customizability, which may hinder their effectiveness across varied classroom levels and environments.

At the University of Central Oklahoma (UCO), faculty have a strong focus on transformative educational experiences for undergraduate students, directed in part by our mission statement that UCO exists “to help students to learn by providing transformative education experiences to students so that they may become productive, creative, ethical and engaged citizens and leaders serving our global community”. UCO is a mid-sized, regional state university (ca. 11,800 undergraduate students in Fall 2021), as well as a metropolitan institution, with nearly 70% of students drawn from the Oklahoma City metropolitan area. This contributes to a diverse undergraduate demographic, including ca. 45% of undergraduate students self-identifying as minority or international, and a high percentage of non-traditional students (63%) of undergraduates 21 years or older). Within UCO’s College of Mathematics and Science, the Department of Biology’s introductory biology course series for science majors is divided into two, semester-long courses. One course, Biology 1204 (Principles of Biology) covers traditional cell and molecular biology concepts, including cellular respiration, as well as the scientific process, evolution and the Anthropocene. The second course, Biology 1225 (Diversity of Life), covers life’s diversity as well as ecological foundations. Biology 1204 is taught in a small-section format (maximum 40 students/section, 4–8 sections/semester), which is amenable to active learning strategies. These strategies are further encouraged to ameliorate the relatively high ‘DFW’ (D-grade, F-grade, withdrawal) rates common to introductory science courses, and because Biology 1204 currently lacks a laboratory component.

As an instructor for Biology 1204, I recognized that my students were consistently challenged by the topic of cellular respiration, as evidenced by exam scores across semesters and sections. Although online virtual labs and study questions (both provided by our textbook publisher) and a worksheet exercise are used in my sections to help students learn this material, neither seems to find great success in increasing student comprehension of this difficult topic. Considering this, I created and tested an original board game, designed to help students comprehend and retain critical details of cellular respiration. The board game incorporates a variety of learning and game strategies, including answering multiple choice quiz-type questions, chance-connected learning through dice-rolling, quantitative visual assessment of the relationships between pathways, electron carriers and ATP, and surprise/strategy cards to keep the game somewhat unpredictable and to level the playing field between students of different knowledge levels. The game board is a fully connected visual representation of the pathways of cellular respiration, including fermentation, which allows students to spend time making connections between pathways and cellular compartments while playing the game. Major components of the game, including the game board and quiz-type questions, are fully editable to suit individual instructors’ needs. Finally, students may fill out a study table as they progress through the game, including self-assessment of their understanding of each of the major pathways of cellular respiration. This table can be turned in for credit at the end of the game-playing session, and ultimately used as a study resource when students prepare for an associated exam.

Intended Audience

This lesson was used in a small section (ca. 25–30 students) of my introductory biology course for science majors at the University of Central Oklahoma, with enrollment mainly consisting of first- and second-year science (Biology, Chemistry, Biomedical Sciences) majors. While the intended audience is primarily undergraduate introductory biology students, the game may also be utilized for advanced high school students, or upper level undergraduate biology students. For upper level students, the game may best be applied as a review activity to reinforce information learned in previous courses. Included in the supporting materials are suggested game card and game board versions for all three academic levels that are further editable to suit instructor preferences.

Required Learning Time

For an undergraduate introductory biology class, this Lesson is intended to be completed in a single, ca. 60- to 90-minute class or laboratory period, although instructors may allocate a longer period of time or parts of multiple class/laboratory sessions depending on students’ performance and progress through the game. Alternatively, the Lesson could be offered as a reserve item in a school library for student study or as
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a take-home assignment/extra credit activity. For advanced high school students, instructors may choose to divide the game across multiple classroom or laboratory sessions or use accompanying short educational videos for each pathway, for example to align game progress with student learning of individual pathways. For advanced undergraduate students, instructors may prefer to assign the game as a review or extra credit assignment to be completed outside of class time.

**Prerequisite Student Knowledge**

Students are expected to have a basic understanding of the pathways of cellular respiration before this Lesson, including glycolysis, pyruvate oxidation, the citric acid cycle and mitochondrial electron transport/oxidative phosphorylation, as well as fermentation. This Lesson is therefore intended to be applied after an instructor has covered cellular respiration in a lecture or comparable format.

**Prerequisite Teacher Knowledge**

Instructors should have a reasonable understanding of the pathways of cellular respiration in order to effectively facilitate this lesson, including for glycolysis, pyruvate oxidation, the citric acid cycle and mitochondrial electron transport/oxidative phosphorylation, as well as fermentation. Of particular importance are inputs and outputs of each pathway, tallies of ADP/ATP, NAD+/NADH, and FAD/FADH₂, and keeping track of the carbons originating in glucose, although other details are also covered in the quiz question cards utilized in the game. The instructor should also be familiar with the rules of the game prior to classroom use, so that they may easily answer any questions students have on technical game-play issues.

**SCIENTIFIC TEACHING THEMES**

**Active Learning**

The overriding active learning strategy for this Lesson is game play, which has been demonstrated as an effective tool for STEM learning (4). Application of this board game provides an interactive learning environment for students, in which they are invested in learning in order to both perform well in the game and potentially win the ‘ATP jackpot’. The game may be played by from two to eight students, playing singly or in teams of two students, the latter of which may facilitate discussion and debate between teammates on the details of cellular respiration. Game play is expected to be wholly completed by students, with an instructor only providing oversight and assistance with questions on the rules of the game, when necessary.

**Assessment**

Students may complete a provided study table during the course of game play. This increases students’ active participation in their own learning, which has demonstrated benefits for students of diverse backgrounds (10). This table can be treated as a points-based assignment, and used for assessment of student learning success by the instructor. Students are also able to assess how well they understand each pathway of cellular respiration, by tracking the percent of questions they answered correctly for each pathway.

**Inclusive Teaching**

In designing this game, I attempted to follow Universal Design of Instruction principles (11) within the confines of a non-digital board game. Students participate in what is designed to be a low-stress and inclusive game-playing environment. Students may play as either single-players or two-player teams, which provides flexibility to students who are more, or less, independent or confident in their understanding of cellular respiration. The ability to play as a small team may also improve cooperation and social interaction among students (7). The game also relies on varied traditional game techniques, including knowledge questions, dice-rolling/chance, and ‘surprise’ cards, so that students have multiple ways in which they can progress through the game or level the playing field, and so that the game is not entirely predictable or necessarily dominated by high-achieving students. Last, the game board design and the use of standard poker chips to represent molecules (NAD+/NADH, FAD/FADH₂, ADP/ATP, ½O₂/H₂O), is targeted toward engaging students that favor visual and tactile learning. Board game and chip design utilize color to accommodate visual learners, and text to minimize impacts of potential color vision limitations in students. Game board design was also checked against the Color Blindness Simulator application (12), with the goal that students with color-limited vision would still be able to reasonably maneuver through the game. The use of colored player pieces is one aspect of the game that may still affect students with color-limited vision, since player pieces are only unique by color. Instructors may choose to uniquely mark these pieces, or use alternative player pieces (different shapes or objects, for example Monopoly™ game pieces).

**LESSON PLAN**

This game is intended to be used in the classroom or active learning laboratory after the instructor has completed course lectures on cellular respiration and fermentation, and could be completed in a single 60–90-minute class or laboratory period (Table 1). The instructor is expected to print and assemble the game board and game pieces prior to use. The recommended materials and game pieces are purchasable online, and are relatively affordable. Aside from printing of the game board, the materials cost for a single game is ca. USD 50, while the cost for five game setups is ca. USD 80 since most ordered materials come in sufficient quantity to cover multiple game setups. Each game setup can accommodate from 2–8 students, so five game setups would accommodate a class of up to 40 students, for example.

The game board itself is included as an editable PowerPoint file (Supporting File S1), and should be printed in color at approximately 30” by 30” square. Game cards are printed on colored card-stock paper, and are also available in an editable PowerPoint file (Supporting File S2). Game pieces, including dice, poker chips (and labels) and pawns, are available online (Supporting File S3). Different colored poker chips are used as molecules during game play (white – ADP/ATP, red – NAD+/NADH, red/black – FAD/FADH₂, blue – ½O₂/H₂O). Initial assembly of game pieces does take a substantial amount of time (estimated ca. 1 hour per game setup); however, once game
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assembly is complete, setup prior to play takes only a matter of a 1-several minutes if game pieces are kept organized. Game chips can be labeled either using printed round labels or by hand; the latter would save slightly on cost and possibly assembly time.

Figure 1. Example setup for Aerobic Respiration: The Board Game. Each player/team on a side of the board starts with the following: 1) a red, green, blue or yellow player piece matching the colored text along their side of the board, and placed in the ‘start here! G1’ location at the top left of the board, 2) eight ADP/ATP chips (white), 3) ten NAD+/NADH chips (solid red), 4) two FAD/FADH2 chips (red/black), and 5) one ½O2/H2O chip (blue). Color-coded game cards are arranged as shown for each pathway (pink=glycolysis, green=pyruvate oxidation, blue=Krebs cycle, yellow=oxidative phosphorylation, white=fermentation, orange=scientific process). ATP jackpot (lower right) is filled with 32 ADP/ATP chips, and is the final goal for players/teams. Game board shown is the original design; updated designs are also available in Supporting File S1.

Setup of the game mainly involves placing game cards of two types, ‘question’ and ‘pass’ cards, in designated boxes for each pathway of cellular respiration on the game board (Figure 1). Stacks of question cards are also kept covered with ‘cover’ cards, so that students cannot see which card will be drawn next. Various ‘special’ cards (described below) are also shuffled in with each set of question cards, with the exception of fermentation question cards.

The complete rules of the game are provided in Supporting File S4, and following is a brief description of game play. Students first choose a colored pawn (red, green, blue or yellow) as their playing piece, corresponding to the color-coded side of the game board on which they are sitting. Each player/team is also allocated a collection of chips they will use as they pass through each metabolic pathway—a total of eight ADP/ATP, ten NAD+/NADH, two FAD/FADH2, and one ½O2/H2O chips. In addition, 32 ADP/ATP chips are placed in the ATP jackpot (Figure 1), with ADP-side up. Play begins with all pawns in the game board location labeled ‘start here! G1’ (i.e., ‘Glycolysis 1’, the beginning of glycolysis) (Figure 1). The starting player or team is selected by roll of the dice, and play proceeds in a clockwise manner between players/teams. At position G1, the first player/team places one ADP/ATP chip on the first ATP circle (ATP-side up), and attempts to answer the top glycolysis question card. If the question is answered correctly, the player/team flips their ATP chip over to the ADP circle, and then moves the chip to the gray ADP circle on their side of the board, also replacing the question card to the bottom of its pile. The player/team then moves their pawn to position G2, and repeats the process. A player/team is limited to moving up to two places per turn, and a turn ends after any incorrect answer. Play proceeds in this manner through glycolysis (positions G1 through G5), with players/teams placing the appropriate chips at each position, and flipping chips and moving them to the appropriate location on their side of the board after each correct answer to a question card. When a player completes position G5 by answering a
question correctly, they then draw a glycolysis pass card, for which they will roll the dice to determine if they pass on to pyruvate oxidation. Pass card dice-rolls are also knowledge-based, for example a player/team may have to roll a number greater than the number of carbon atoms in pyruvate in order to pass through to pyruvate oxidation (position PO1).

As players progress through glycolysis (positions G1–G5), pyruvate oxidation (positions PO1, PO2) and the Krebs cycle (positions KC1–KC5) (Figure 1), they accumulate stacks of NADH, ADP/ATP and FADH₂, chips on their side of the board, providing visual perception of how these molecules accumulate from each of these pathways. The NADH and FADH₂ chips are ‘spent’ when players/teams progress through the electron transport chain (positions ETC1–ETC3), again by answering associated question cards. In order to win the game, a player or team must be the first to capture the ‘ATP jackpot’ after the electron transport chain. To capture this jackpot, a player/team must answer a final ‘Scientific Process’ card at position SP1, and have all players/teams agree that their answer is correct. Scientific Process cards describe simple (hypothetical) experiments on respiration, and students are tasked, for example, with determining null and alternative hypotheses, or independent and dependent variables. A player/team that captures the ATP jackpot may flip the 32 ADP/ATP chips so that they are ATP-side up, and the instructor may choose to provide additional prizes for game winners, as well as second-, third-, and fourth-place finishers.

Game play also includes various ‘special’ cards, that are shuffled into the question cards for each pathway. As one example, a player/team may draw a ‘No oxygen! Go to fermentation jail!’ card, in which case the player/team must move their pawn to the fermentation pathway, and answer a fermentation question correctly in order to resume play. Alternatively, a ‘Bounce Card!’ card can be used to transfer the effects of a ‘Fermentation jail!’ card to any other player/team. A player could also draw a ‘This card is poison!’ cyanide card, which would allow them to strategically block all players’ progress past complex IV of the electron transport chain.

Finally, during the course of game play, players may fill out a study table (Supporting File S5). This (instructor-customizable) table is focused on key components of each pathway, in particular inputs and outputs including NADH, FADH₂, and ATP. Students are also able to gauge their understanding of each pathway by tallying their correct and incorrect answers to each pathway’s question cards, in designated locations on the table. This table may also be turned in at the conclusion of the game, to be assessed/graded by the instructor.

TEACHING DISCUSSION

I used Aerobic Respiration: The Board Game in one section of our Biology 1204 course in the Fall 2022 semester. Approximately 25 students participated in the game, and eleven students completed an anonymous and voluntary online pre- and post-survey questionnaire (approved by UCO IRB, Application #2022-063). I left the classroom while students completed the survey questions. The pre/post-survey included a set of eight multiple-choice questions covering aspects of each of the pathways of cellular respiration, including fermentation, as well as five Likert-scale questions assessing students’ overall opinions of the game (survey and results are provided in Supporting File S6). Students answered the same eight multiple-choice questions both before and after game-play in order to assess learning gains, while Likert-scale questions were answered only after game-play.

In my initial test of the game, students were tasked with game setup, learning the rules and playing the game, and completing the pre- and post-survey online questions, all within a single 50-minute class period. This combination proved too time-consuming, and as a result, most student groups only progressed partly through glycolysis or into pyruvate oxidation during game play. From this experience, I recommend using this game in a longer class period (60–90 minutes) and having the instructor set up game boards and pieces prior to class. Although students worked on the included study table during game-play, study tables were not collected at the end of the class due to unanticipated disorganization in the short time between my class and a subsequent class. Because of my students’ limited progress through the game, pre/post-survey multiple-choice questions relating to earlier pathways in cellular respiration are most informative regarding potential gains in learning. Student performance improved by ca. 17% in correctly identifying the location of glycolysis, and by ca. 8% when identifying the location of the carbons of glucose after glycolysis, as well as the cellular location of the Krebs cycle. None of these results, however, were significant (p values for paired student’s t test ranged from 0.169–0.293). Student performance on the remaining five multiple-choice questions (focusing on subsequent details of aerobic respiration and fermentation) was variable and ranged from negative to no change, although again results were not significant. Likert-scale responses indicated significantly favorable views of the game and its use as a teaching/learning tool (Table 2). In particular, question and pass cards were indicated as helpful in learning and understanding the details of the pathways, as was the visual organization of the game board. Students also indicated that they would like to learn other biology topics in a game format.

In an optional comment section on the post-survey, students indicated that the instructions for the game were somewhat overwhelming, and that the design of the game board was “very busy”. Based on these comments, I made several adjustments to the board game design and the game instructions, with the goal of simplifying the game board without sacrificing critical details, and streamlining and clarifying the instructions. Game board modifications included color-coding of playing positions for each pathway and removal of extraneous cell biology details. As an example of the latter, the original game board included a small visual representation of primary and secondary active transport in one corner of the game board, which is a topic covered prior to cellular respiration in Biology 1204. While this change does simplify the design of the game board, it may still be useful to include this graphic if students spend relatively more time playing the game. This would allow them to simultaneously review and make connections between multiple topics in cell biology. I have included the original (as shown in Figure 1) and two simplified versions of the game board in Supporting File S1, all of which are able to be further modified to suit the needs of instructors and courses taught at differing academic levels.

Last, since an additional cellular respiration-based board game adaptation has been previously published (9), it is reasonable to compare this effort with Aerobic Respiration: The Board Game. Between these two games, overall cost is...
expected to be roughly similar since a single new Mouse Trap board game currently costs ca. USD 20–30. Alternatively, (9) recommends only 2–3 or up to 6 students per game setup rather than 2–8 students per setup for my game, so overall materials costs for my game may be slightly lower. My board game may benefit students by using a less abstract representation of cellular respiration pathways, although this benefit could apply more clearly to students at higher academic levels since they are less likely to feel overwhelmed by a game board with a high level of molecular detail. Question cards in Aerobic Respiration: The Board Game are also designed to reflect typical exam questions, while the student-completed study table should provide a helpful resource for students’ exam preparation. Ultimately, it is my hope that the Aerobic Respiration: The Board Game will complement similar resources, while providing additional flexibility to instructors since the board game and playing cards are customizable to reflect instructor preferences and academic level.

SUPPORTING MATERIALS

• S1. Aerobic Respiration – Game Board
• S2. Aerobic Respiration – Game Cards
• S3. Aerobic Respiration – Materials List and Assembly
• S4. Aerobic Respiration – Game Rules
• S5. Aerobic Respiration – Study Table
• S6. Aerobic Respiration – Pre-/Post-Survey Questions and Results

ACKNOWLEDGMENTS

I would like to thank the students in my Fall 2022 semester of Biology 1204 for participating in playing this board game and completing the pre-/post-survey. I would also like to express my thanks for the UCO Department of Biology for supporting the development and testing of this board game learning tool.

REFERENCES

Table 1. Lesson Timeline. For an undergraduate introductory biology course, this Lesson would typically be used within a single, 60–90 minute class or laboratory period, and used after lectures on cellular respiration.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
<th>Estimated Time</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Preparation for Class</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provide students with lecture or equivalent background material on the pathways of cellular respiration</td>
<td>Instructors should use this game in class or lab after students have already learned the pathways of cellular respiration</td>
<td>Typically, this would involve several standard lecture periods</td>
<td>It is important that students have already been exposed to the pathways of cellular respiration prior to playing this game, since game questions are largely based on details of these pathways.</td>
</tr>
<tr>
<td>Set up game</td>
<td>Instructor lays out game boards, organizes cards and chips for each game setup</td>
<td>15–20 minutes</td>
<td>Depending on time constraints, instructor can provide little to complete game setup for students prior to class.</td>
</tr>
<tr>
<td><strong>Class Session</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Game introduction</td>
<td>Briefly introduce students to game, including goals and basic rules</td>
<td>5–10 minutes</td>
<td>Provide students with game rules. Instructor may also want to provide a short demonstration with selected students, or create a brief video tutorial.</td>
</tr>
<tr>
<td>Game play</td>
<td>Students play game</td>
<td>50–80 minutes</td>
<td>Ideally all students will have a chance to finish all pathways of the game. Instructor may want to have some type of prizes for students when they complete the game. Students should also focus on completing their study tables during game play.</td>
</tr>
<tr>
<td>Study table</td>
<td>Students turn in completed study table</td>
<td>5 minutes</td>
<td>Table may be used as an assessment tool/assignment.</td>
</tr>
</tbody>
</table>
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Table 2. Results of post-survey Likert prompts for students playing Aerobic Respiration: The Board Game. Each prompt was rated by students as follows: 1=strongly disagree, 2=somewhat disagree, 3=neutral, 4=somewhat agree, 5=strongly agree. Additionally, \( p \) values shown are for two-tailed student’s \( t \) test, testing for difference between average response value and a neutral response (i.e., rating=3).

<table>
<thead>
<tr>
<th>Likert Prompt</th>
<th>Average rating ± standard deviation (n=11 students)</th>
<th>( p ) value for two-tailed ( t ) test</th>
</tr>
</thead>
<tbody>
<tr>
<td>I enjoyed playing Aerobic Respiration: The Board Game.</td>
<td>4.09 ± 0.9</td>
<td>0.0025</td>
</tr>
<tr>
<td>I learned more about cellular aerobic respiration in a game format compared to a traditional lecture format.</td>
<td>3.91 ± 1.16</td>
<td>0.0264</td>
</tr>
<tr>
<td>I would like to learn other biology topics in a game format.</td>
<td>4.18 ± 0.72</td>
<td>0.0003</td>
</tr>
<tr>
<td>The visual organization of the game board used was helpful to me to learn and understand the pathways and locations of cellular aerobic respiration.</td>
<td>4.27 ± 0.86</td>
<td>0.0006</td>
</tr>
<tr>
<td>The ‘question’ and ‘pass’ cards for each pathway helped me to learn and understand the details of cellular aerobic respiration.</td>
<td>4.55 ± 0.66</td>
<td>0.0001</td>
</tr>
</tbody>
</table>