

Escape Zoom!: Reviewing Introductory Evolution Content Using an Escape Room Format

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Abstract

Reviewing and integrating key concepts and learning goals at the end of a biology course can be overwhelming to students and instructors alike. Often end-of-term review sessions in preparation for final exams are heavily based on memorization, and content coverage may be favored over students' deeper understanding of fewer key ideas. We developed a final exam review for a virtual introductory evolution course using an "escape room" format, which consisted of unique activities—including puzzles, role-playing, and literature searches—aligned with course learning goals. Similar to a traditional escape room, students needed to collaboratively solve or complete each activity before moving on to the subsequent task. Our escape room activity was conducted virtually via Zoom and included both whole-class and smaller breakout room interactions. We recommend instructors utilize escape rooms as an engaging and effective way to review key concepts in their courses.

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Supporting Materials: Supporting Files S1. *Escape Zoom!* - Instructor Slides (Days 1 & 2); S2. *Escape Zoom!* - Sample Student Response Slides with Instructor Answer Key (Days 1 & 2); S3. *Escape Zoom!* - Synchronous Student Slides (Days 1 & 2); S4. *Escape Zoom!* - Asynchronous Student Slides (Day 1); S5. *Escape Zoom!* - Asynchronous Student Slides (Day 2); and S6. *Escape Zoom!* - Poll Questions (Day 2)

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Learning Goals

Students will:

- collaborate with peers to review basic concepts of evolution.
- appreciate the importance of evolution in modern scientific research.

Learning Objectives

Students will be able to:

- hypothesize appropriate species concepts based on speciation case studies.
- create a phylogenetic tree via interpreting a table of species' characters.
- describe mechanisms of evolution by developing role-play scenarios.
- research diverse evolutionary biologists.
- connect course content (e.g., the Central Dogma) to current news stories (e.g., the use of mRNA technology in COVID-19 vaccines).
- explain a novel example of sexual selection.
- recall important definitions and key concepts related to extinction and deep time.
- list species that have been created via artificial selection.

INTRODUCTION

Evolutionary topics are often confusing for students and frequently lead to the formation of misunderstandings, especially in relation to such ideas as natural selection, microevolutionary processes, and phylogenetic trees, among others (1-4). Students are also introduced to new terminology in evolution courses, which may further impede their abilities to understand important evolutionary concepts and processes (5). Thus, it is essential for instructors to incorporate various active learning techniques and learning modalities when teaching evolution to ensure students are engaged in the content and understanding of foundational concepts and processes. While some student-centered lessons covering basic evolutionary concepts have been published (e.g., 6-8), such activities tend to focus on a narrow scope of evolutionary concepts and were developed for in-person courses.

Developing engaging, fun, and effective learning activities in online biology courses can be challenging, particularly when instructors are limited by the resources they have access to through their institution (e.g., video-conferencing platforms, polling software). When designing teaching materials for non-majors, instructors may feel additional incentive to develop student-centered lessons, as these may be the only biology or science courses that students enroll in during their undergraduate program. In our case, this course was introductory evolution for non-biology majors.

The implementation of escape rooms as learning tools has become increasingly popular in recent years. In our lesson, we adopted Nicholson's (9) definition of an escape room as "a live-action team-based game where players discover clues, solve puzzles, and accomplish tasks in one or more rooms in order to accomplish a specific goal (usually escaping from the room) in

a limited amount of time” (p. 1). Through scaffolded activities or checkpoints, students can engage in deep learning while collaborating with peers to solve puzzles, answer questions, or perform particular tasks (10). As a form of game-based learning, escape rooms have been shown to be interactive and effective in promoting student motivation to learn (10–11). Escape room activities have been developed across STEM disciplines, including biology, engineering, and chemistry, among others (e.g., 12–14), though to our knowledge, none were originally designed for a virtual setting.

We implemented *Escape Zoom!* in Fall 2020 for a non-majors introductory evolution course as an engaging way for students to review course learning objectives for the final exam. *Escape Zoom!* incorporates multiple activities—including puzzles, role-playing, and literature searches—intended to cover a broad range of important evolutionary concepts over two class sessions. Similar to a traditional escape room, students need to collaboratively solve or complete each activity before moving on to the subsequent task. This escape room activity was conducted virtually via Zoom and included both whole-class and smaller breakout room interactions.

The general evolutionary concepts covered in our *Escape Zoom!* activity includes species concepts, mechanisms of evolution, and phylogenetic tree-building.

Intended Audience

This lesson was implemented in an introductory evolution course for non-majors at a four-year research university, though the *Escape Zoom!* activity could be easily adapted for review sessions in biology courses for majors and advanced students as well. There were 65 students in our introductory evolution course. Three instructors were present during both days of *Escape Zoom!*—the primary instructor, the graduate teaching assistant for the course, and a guest instructor/facilitator. Additional instructors could be helpful for activity logistics, though we found three instructors to be sufficient to check in on the approximately twenty groups of three to four students each.

Required Learning Time

We developed this lesson to take place over two 75-minute synchronous online class sessions. We also developed an asynchronous version that students could complete outside of class if they were unable to attend the virtual classes. If they submitted answers and explanations to each of the questions within 24 hours, they received participation points.

Prerequisite Student Knowledge

As this *Escape Zoom!* activity was a review of important concepts from an entire evolution course, students should have achieved the course learning goals and have engaged in all relevant concepts and topics prior to participating in this culminating review. Some of these broader course learning goals included recognizing and correcting common misunderstandings about evolution (e.g., misinterpreting phylogenetic trees [15], believing that species are evolving from simple to complex), differentiating between the four main mechanisms of evolution (natural selection, mutation, migration, and genetic drift), communicating about evolutionary principles to classmates, and describing relevant examples of evolution. Students should also be comfortable

engaging in collaborative work within Zoom breakout rooms using shared Google Drive folders.

Prerequisite Teacher Knowledge

Aside from having foundational evolutionary knowledge, the instructor should be cognizant of their course learning goals for this activity, as the primary purpose of *Escape Zoom!* is to review significant concepts and topics of a course at the end of the term. If you would like to adapt any of the activities outlined in *Escape Zoom!*, we recommend developing activities based on learning objectives that students often find challenging in your course. Additionally, instructors should be comfortable navigating Zoom (e.g., creating breakout rooms, responding to raised hands) and monitoring collaborative student documents on Google Drive. If you would like to gain a deeper understanding of pedagogical issues related to teaching evolutionary concepts, several resources are available (e.g., Table 2 in [16]).

SCIENTIFIC TEACHING THEMES

Active Learning

This lesson relies heavily on collaborative work; students complete each activity in *Escape Zoom!* in small breakout room groups, and variations of think-pair-share are encouraged throughout the lesson. Additionally, students are frequently required to interact with the instructors; instructors provide formative feedback to students for each activity before they are allowed to proceed to subsequent activities. As the eight activities included in this lesson are distinct and incorporate a range of active learning techniques across various evolutionary topics, students have multiple opportunities to engage in the lesson material and achieve the lesson learning objectives. These activities include making predictions in case studies, building phylogenetic trees, role-playing during a charades-like challenge, researching popular and primary resources, presenting findings and ideas to the whole class, solving word puzzles, brainstorming and listing relevant ideas in a “minute paper”-like speed round activity, and responding to live polls.

Assessment

After each activity in *Escape Zoom!*, student groups are required to check in with one of the instructors prior to moving on to the next activity; assessment types include: 1) answering short answer questions and multiple choice poll questions, 2) creating phylogenetic trees 3) role-playing 4) searching for literature and video, and 5) completing crossword puzzles. Additionally, students are working collaboratively and problem-solving in small groups throughout the lesson. Thus, students have multiple opportunities to receive formative feedback (from instructors and peers) and reflect on what evolutionary concepts they need to review in more detail for the final exam. Relevant learning objectives are shared with students on each day of *Escape Zoom!*, although students only receive points for completing the activities rather than for correctness. Each group is required to document their responses within their assigned Google Slides file (Supporting File S3. *Escape Zoom!* - Synchronous Student Slides (Days 1 & 2), Supporting File S4. *Escape Zoom!* - Asynchronous Student Slides (Day 1), Supporting File S5. *Escape Zoom!* - Asynchronous Student Slides (Day 2)). Groups then have access to these Google Slides for the remaining weeks of the course, so that students are able to use their completed activities to review for the final exam.

We should note that individual preparation for Activity 5 in our lesson (i.e., researching COVID-19 mRNA vaccines) was worth additional points beyond the *Escape Zoom!* completion points, as it was assigned as an out-of-class “entry ticket” for Day 2 of the lesson.

Inclusive Teaching

This lesson incorporates a range of learning modalities and course learning objectives; for example, students are asked to solve crossword puzzles, role-play, and present ideas or findings to instructors and/or the entire class. Thus, students are using multiple senses (e.g., oral, visual, mechanical) to complete each escape room activity.

Students have multiple opportunities to express agency and creativity during this lesson; one particularly strong example of this—which also allows students to explore evolutionary biologists with diverse identities—is the activity which asks students to explore the [Project Biodiversify](#) website and summarize three novel things they learned about their chosen biologist.

This activity requires students to work in small groups (e.g., in Zoom breakout rooms), interact with the instructors (e.g., to receive approval before progressing to the next activity), and share ideas with the entire class, so there is potential to foster a sense of community and collaboration throughout the two-day lesson.

LESSON PLAN

The *Escape Zoom!* lesson was implemented virtually on Zoom over two 75-minute class sessions and acted as a review of course learning objectives and important evolutionary concepts for the final exam. Thus, prior class sessions which covered these evolutionary concepts in more detail and at a deeper level throughout the course are not discussed further here, though topics such as natural selection (8), phylogenetic trees (6), and common evolution misunderstandings (17) can be explored more specifically in other *CourseSource* lessons. Students spent the majority of time in breakout rooms with their small groups, though some time was also spent in the larger main room with the whole class. A lesson timeline including activity descriptions and helpful hints is available in Table 1, and all Google Slides documents (i.e., instructor slides to share in class, instructor slides with activity questions and answers, and both synchronous and asynchronous student slides) are available as supporting files.

Before Class

Teacher Preparation

As this lesson was developed for an introductory evolution course for non-majors, instructors are required to have a foundational understanding of evolutionary concepts (e.g., species concepts, mechanisms of evolution, phylogenetic trees). If you would like to review key concepts prior to implementing this activity, we suggest referencing introductory evolution or biology textbooks; further, if you would like to gain a deeper understanding of pedagogical issues related to teaching evolutionary concepts, several resources are available (e.g., Table 2 in [16]).

The bulk of preparation for this lesson is logistical. First, you will need to establish groups of 3-4 students, if students do not collaborate in pre-established groups in your course regularly. We recommend maintaining these same groups throughout both days of *Escape Zoom!*, so that students have a chance to become comfortable with their peers and foster a sense of community.

Once groups are established, you will need to create breakout rooms in Zoom (or an equivalent video calling platform) and a separate *Escape Zoom!* Google Slides file (Supporting File S3. *Escape Zoom!* - Synchronous Student Slides (Days 1 & 2)) for each synchronous student group; this involves ensuring that individuals from each student group gain access to only their group’s slides. We set the share function on the slides so that the instructors and only students with a specific email address could edit. We recommend that these links stay hidden until Day 1 of *Escape Zoom!*, so that students are not tempted to work ahead, and that links are posted in an easily accessible location (e.g., on your course’s Learning Management System, or LMS). If you know that certain individuals will not be able to attend one or both days of the synchronous class sessions, you can send individual emails to these students asking them to complete the activities in the Asynchronous *Escape Zoom!* Google Slides by a certain deadline; we used 48 hours from the end of class (Supporting File S4. *Escape Zoom!* - Asynchronous Student Slides (Day 1) and/or Supporting File S5. *Escape Zoom!* - Asynchronous Student Slides (Day 2)). A reminder about how to complete and submit the *Escape Zoom!* activities is also available in the instructor slides shared with students on both days of the lesson (S1. *Escape Zoom!* - Instructor Slides (Days 1 & 2)).

If you need to revise any of the content or concepts incorporated in the activities to align better with your course learning goals, this preparation stage is an ideal time to do so. Additionally, you can update certain areas of the instructor slides to better tailor the lesson to your class (e.g., filling in deadlines, your course LMS, instructor contact information), and revise the current order of activities to better suit your course needs. If you would like to make *Escape Zoom!* a friendly competition among groups, you should also consider whether you want to offer students points for completing each activity; in our course, the only activities which separated student groups from one another point-wise were correct responses and the bonus riddle on the crossword puzzle (Activity 7), and the number of items listed in the speed round (Activity 8). For example, students received one point for each correct response on Activities 7 and 8, and two additional points if they solved the crossword riddle, and the “winning” group was announced in a follow-up email after the lesson. However, all students received participation points if they completed the synchronous or asynchronous activities during the two lesson days.

Student Preparation

As students have been learning and applying important evolutionary concepts and topics throughout the course, there is no additional preparation required of students for this lesson.

During Class

Day 1

Introducing the lesson (10 minutes)

Even if you discussed the *Escape Zoom!* lesson in preceding class sessions, we suggest beginning Day 1 reminding students of the lesson expectations, format, logistics, and learning objectives (Slides 3-5), format, and other logistics, using the instructor slides to guide you (Supporting File S1. *Escape Zoom!* - Instructor Slides (Days 1 & 2)). Another important aspect of the lesson that you should mention to students at this time is how they will receive feedback for each activity. When we implemented *Escape Zoom!* in our course, we asked students to use the “Ask for Help” function in Zoom so that one of the instructors could join the group’s breakout room and informally evaluate the group’s responses or tasks on an activity for accuracy and completeness. If students sufficiently completed an activity, we would grant them permission to move on to the next activity; if students needed to revise their response in some way, we would offer feedback to the group and instruct them to alert us when they were ready to proceed. While many of the activities do not have a single correct answer/response, those that do are outlined in red text throughout the instructor answer key slides (Supporting File S2. *Escape Zoom!* - Sample Student Response Slides with Instructor Answer Key (Days 1 & 2)). Lastly, before sending to their pre-assigned breakout rooms, remind students where they can access their group’s Google Slides link for the lesson, and that they should expect intermittent messages throughout the lesson updating them on timing.

Activity 1 (10 minutes)

In Activity 1, students are asked to read a short case study on African cichlid speciation and respond to three questions (covering topics of species concepts, gene flow, and natural and sexual selection), which instructors will then check for accuracy (and potentially ask follow-up or clarifying questions about; Slides 3-4 in Supporting File S3. *Escape Zoom!* - Synchronous Student Slides (Days 1 & 2)).

Activity 2 (20 minutes)

In Activity 2, students are asked to fill in a trait table after viewing trait cards for seven different vertebrates and subsequently complete a partially constructed phylogenetic tree based on their filled-in trait table; this activity was adapted from the Vertebrate Clade Race developed by Baum and Jenkins (18) and the Great Clade Race developed by Goldsmith (19). “Partially completed” refers to the fact that the branches of the tree, as well as two of the organisms and one of the traits, are pre-populated in the Google Slide to ensure students can complete this activity in the allotted ~20 minutes. Students simply need to drag the text boxes containing the organism names and traits to the corresponding location on the phylogenetic tree, which the instructors will check for accuracy (Slides 5-8 in Supporting File S3. *Escape Zoom!* - Synchronous Student Slides (Days 1 & 2)).

Activity 3 (10 minutes)

In Activity 3, students are asked to brainstorm in their groups how to visually represent or act out each of the four mechanisms of evolution (i.e., mutation, migration, genetic drift, and natural selection), and jot their ideas down in the corresponding Google Slide (Slides 9-10 in Supporting File S3.

Escape Zoom! - Synchronous Student Slides (Days 1 & 2)). Instructors then ask students to perform one of the mechanisms of evolution the students had practiced and follow-up with clarifying questions or feedback; of course, instructors are welcome to ask students to perform more than one mechanism, if time allows and groups are feeling creative. For example, one group demonstrated natural selection by putting on hats that either blended in with their Zoom background, or did not camouflage well with their background, modeling that organisms who camouflage more successfully in their environment are at a lesser risk of predation and that this trait may be passed onto offspring over time.

Activity 4 (15 minutes)

In Activity 4, students need to navigate to the Evolution page on the [Project Biodiversity](#) website and search through the featured evolutionary biologists. Project Biodiversity is—according to their [website](#)—“a repository of teaching materials and methods aimed at enhancing human diversity and inclusivity in biology courses.” Instructors can find teaching resources (e.g., ready-to-use slides) highlighting research from diverse biologists. Students are asked to choose a biologist they have never heard of and who conducts (or conducted) evolutionary research that their group finds interesting, and write down three facts about this person as well as explain how what they research (or researched) relates to at least one concept that was covered in the course (Slides 11-12 in Supporting File S3. *Escape Zoom!* - Synchronous Student Slides (Days 1 & 2)). For example, one group chose to learn about Dr. Nicole Soltis, an evolutionary biologist who studies plant diseases and advocates for science communication in plant biology. They related Dr. Soltis’ research about tomato plants and pathogens to concepts of natural selection they had learned about in class. Students can either ask an instructor to join their breakout room to have their responses checked, or they can return to the main Zoom room to do so, as this is the last activity scheduled for Day 1 of *Escape Zoom!*

Wrap-up (15 minutes)

Once all breakout rooms have closed and students return to the main Zoom room, instructors may ask 1-2 groups to share their charades or Project Biodiversity activity, time-permitting. Remaining time should be used to answer students’ questions about the learning objectives covered in the Day 1 activities, as well as discuss the Day 2 “entry ticket” assignment with students (Slide 6 of Supporting File S1. *Escape Zoom!* - Instructor Slides (Days 1 & 2)), including reminding students of where to access the assessment, the due date, and how the assessment will be scored (e.g., for participation, completeness, accuracy).

Out-of-Class

“Entry ticket” (pre-assessment) for Day 2 (20-30 minutes)

Prior to Day 2 of *Escape Zoom!*, students individually complete a pre-assessment to help them prepare for Activity 5 (i.e., the first activity on Day 2). In this pre-assessment, students are asked to respond to the following prompt on a discussion board within the course LMS: *The COVID-19 vaccines developed by companies such as Pfizer and Moderna use novel mRNA technology. How does this technology work? Find a news article, podcast, or video and paste the URL here.*

In a few sentences, summarize in your own words how the vaccine works and how it is different from previous vaccines. In our course, we only graded students for completing the assessment, as student responses can be quite variable for this discussion.

During Class

Day 2

Introducing the lesson (5 minutes)

Even if you discussed the *Escape Zoom!* lesson on Day 1, we suggest beginning Day 2 reminding students (particularly those that may not have participated in Day 1!) of the lesson expectations, format, logistics, and learning objectives (Slides 8-10), format, and other logistics, using the instructor slides to guide you (Supporting File S1. *Escape Zoom!* - Instructor Slides (Days 1 & 2)). See Day 1 - Introducing the lesson above for a more detailed description regarding what to discuss with students before commencing Day 2 activities.

Activity 5 (10 minutes)

In Activity 5, students are asked to create a teaching slide about COVID-19 mRNA vaccines based on what each individual learned from the “entry ticket” pre-assessment. Students are invited to be as creative as they would like in developing this slide and are encouraged to include relevant photos and diagrams. When finished, students will give a 2-3 minute presentation on what they learned about COVID-19 mRNA vaccines, using their teaching slide to support their ideas (Slides 15-16 in Supporting File S3. *Escape Zoom!* - Synchronous Student Slides (Days 1 & 2)). For example, most groups used a diagram they created or adapted to explain how mRNA COVID vaccines work, while one group creatively developed an analogy about how mRNA vaccines were like making a cake (i.e., a self-synthesized antigen) from a homemade recipe.

Activity 6 (20 minutes)

In Activity 6, students are instructed to find a short video (i.e., approximately 5 minutes or less) about sexual selection that has not been previously shared in the course and that their group finds interesting or entertaining. Students are asked to consider what principles of sexual selection are being presented (e.g., male to male combat, mating rituals) and what characteristics of the males and/or females in their selected video would make them ideal mates for the opposite sex, as well as include the URL for their video (Slides 17-18 in Supporting File S3. *Escape Zoom!* - Synchronous Student Slides (Days 1 & 2)). For example, one group found a short video about male frogs “serenading” female mates with singing rituals, and discussed how frogs with the longest, loudest, and most complex vocals were most sexually fit and how male frogs fight with one another to successfully latch onto female mates after singing. Instructors can ask follow-up questions about the content of the video and any relevant sexual selection concepts discussed.

Activity 7 (20 minutes)

In Activity 7, students are asked to complete a crossword puzzle with clues based on the topics of extinction and deep time. Once groups have solved each clue, they are challenged to answer a bonus riddle (for extra points, if you are keeping track of *Escape Zoom!* points for a friendly competition). The answer to this riddle involves unscrambling all letters written

in purple boxes on the crossword (Slides 19-22 in Supporting File S3. *Escape Zoom!* - Synchronous Student Slides (Days 1 & 2)). Instructors can check for accuracy on this activity, as well as offer hints if students are stuck on certain clues. While all groups in our course finished this activity, you may need to end Activity 7 early if time is running short and you intended to have students complete Activity 8 (i.e., the speed round). Students are then instructed to return to the main Zoom room once they complete Activity 7.

Catch-up (5 minutes)

This period accounts for groups finishing Activity 7 at different times, and also offers a chance for students in the main room to ask additional questions about the material.

Poll/Review Questions (5 minutes)

At this point, all breakout rooms should be closed and all students should be in the main Zoom room. As we wanted to help our students review the concept of rotating cladograms at a node, we incorporated two poll questions related to this topic which required students to review their responses from Day 1 – Activity 2 (i.e., building a phylogenetic tree). Students responded to these questions in Poll Everywhere (Supporting File S6. *Escape Zoom!* - Poll Questions (Day 2)), and we asked for volunteers to discuss their responses to each question. If you planned for this to be a friendly competition, this also provides time for one of the instructors to tally points for each student group.

Activity 8 (5 minutes)

As Activity 8 is a speed round lasting only one minute, you will want to briefly mention the guidelines of the speed round to students while they are still in the main Zoom room (i.e., that they will be sent to breakout rooms for only one minute, and that they should list as many accurate responses as possible on their designated Activity 8 Google Slide). Then, you can share the prompt with students (Slide 11 in Supporting File S1. *Escape Zoom!* - Instructor Slides (Days 1 & 2)), which they have not yet had access to. You could also keep the Activity 8 slide—with prompt—hidden from students until this point in *Escape Zoom!*, though this may not be logistically feasible. Screen share the following prompt with students, and also copy and paste it in the chat so that students have access to it in their breakout rooms: *List as many species as possible that you can think of that have been artificially selected/bred by humans.* After one minute, students will return to the main Zoom room.

Wrap-up (5 minutes)

Once all breakout rooms have closed and students return to the main Zoom room, you can answer any remaining questions regarding the lesson learning objectives from students. If you planned for this to be a friendly competition, this also provides time for one of the instructors to tally points for each student group, and potentially announce a “winner” (though we did not announce a “winner” until after the lesson in a follow-up email due to time constraints). Keep in mind that there are numerous correct responses to Activity 8, so scoring this portion of *Escape Zoom!* may not be feasible in the last few minutes of the lesson. Students should continue to have access to their group’s completed activities and Google Slides until the end of the course, so that they can use these materials to study for their final exam.

TEACHING DISCUSSION

Achieving the Activity Learning Goals and Objectives

The primary learning goal of this activity was for students to collaborate with peers to review basic concepts of evolution, and secondarily, to appreciate the importance of evolution in modern scientific research. Based on our frequent instructor check-ins with student groups throughout this lesson and groups' responses in their respective Google Slides files, the *Escape Zoom!* lesson offered ample opportunity for students to achieve these goals in an effective, fun, and engaging way. The multiple instances of formative feedback, as well as peer-peer and peer-instructor interactions, ensured that students understood the lesson instructions, achieved the learning objectives for each activity, and clarified misunderstandings or "muddy points" regarding evolutionary concepts. While we only graded group responses on the *Escape Zoom!* Google Slides for participation and completeness, the depth, accuracy, and creativity in students' responses and presentations suggested that the majority of students had grasped the important evolutionary concepts reviewed in this lesson. Additionally, *Escape Zoom!* was intended to serve as a review for the final exam in our evolution course, and questions on the final exam generally aligned with the learning objectives of the *Escape Zoom!* lesson.

Student Reactions to the Activity

Students seemed very appreciative during and after this lesson to have two class sessions dedicated entirely to reviewing course learning objectives for the final exam. Additionally, after the lesson, multiple students expressed their gratitude for the breadth of activities and topics incorporated into *Escape Zoom!*, as well as how engaging, creative, and fun these activities were to complete in their small groups. Some individuals and groups also shared their favorite (and least favorite) activities with the instructors, and based on this anecdotal evidence, different students noted a preference for engaging with different active learning techniques and/or different evolutionary concepts. This feedback could suggest that the range of evolutionary topics and learning modalities incorporated throughout *Escape Zoom!* were conducive for student learning, engagement, and interest.

Improvements for Future Iterations of the Activity

The main challenge we experienced while implementing *Escape Zoom!* was time management; as the instructor, you should be vigilant about staying on schedule (see Table 1 for the suggested lesson plan)—though, of course, you can monitor whether students need more or less time on certain activities and adjust the schedule accordingly. Particularly because this lesson is designed for the virtual classroom, we found it extremely helpful to broadcast frequent messages to breakout rooms regarding remaining time for each activity as well as elicit feedback regarding each group's progress when we checked in with each breakout room at the end of each activity. Further, we found that for activities which required more creativity and problem-solving (rather than recalling information or researching sources online)—such as Mechanisms of Evolution Charades or Creating a COVID mRNA Vaccines Teaching Slide—students generally needed more time to complete each activity.

Moreover, we had three instructors in class during both days of *Escape Zoom!*—the primary instructor, the graduate teaching assistant for the course, and a guest instructor/facilitator. Depending on how large your course is and whether you have access to additional instructors or facilitators, you may need to brainstorm alternate options for providing formative feedback after each activity. Additional instructors are also helpful for activity logistics (e.g., ensuring students have access to their group's Google Slides link, joining breakout rooms when groups have questions, keeping track of timing) and scoring activities, if you choose to make *Escape Zoom!* a friendly competition among groups. As *Escape Zoom!* runs most effectively when student groups finish at approximately the same time each lesson day, instructors may also need to be flexible and have a plan if students finish certain activities quickly or need more time to effectively complete tasks.

Multiple aspects of this lesson can be adapted to better align with your course learning objectives and the needs of your students. For example, while students seemed to enjoy the pre-assessment or "entry ticket" for Activity 5 in our course, you could remove this discussion if you do not want to assign out-of-class assessments related to *Escape Zoom!*. If you emphasized different evolutionary concepts in your course, you could maintain the active learning techniques for each activity while revising the content to better align with your course learning objectives. Similarly, our scoring scheme was informal, in that student groups received an arbitrary number of points for completing each activity that did not have a single set of correct answers, and one point for each correct answer on the crossword puzzle (Activity 7), one bonus point for solving the crossword riddle (Activity 7), and one point for each correct item they listed in the speed round (Activity 8). We wanted *Escape Zoom!* to be a low-stakes review for students and thus did not offer any "prize" for winning beyond announcing the team with the most points in a follow-up email to the class. However, you could develop a more detailed scoring scheme if you wanted to more formally grade this assessment, though we caution that doing so may influence students' willingness to participate and collaborate with peers.

SUPPORTING MATERIALS

- S1. *Escape Zoom!* - Instructor Slides (Days 1 & 2)
- S2. *Escape Zoom!* - Sample Student Response Slides with Instructor Answer Key (Days 1 & 2)
- S3. *Escape Zoom!* - Synchronous Student Slides (Days 1 & 2)
- S4. *Escape Zoom!* - Asynchronous Student Slides (Day 1)
- S5. *Escape Zoom!* - Asynchronous Student Slides (Day 2)
- S6. *Escape Zoom!* - Poll Questions (Day 2)

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REFERENCES

1. Meir E, Perry J, Herron JC, Kingsolver J. 2007. College students' misconceptions about evolutionary trees. *Am Biol Teach.* 69.
2. Abraham JK, Meir E, Perry J, Herron JC, Maruca S, Stal D. 2009. Addressing undergraduate student misconceptions about natural selection with an interactive simulated laboratory. *Evolution: Educ & Outreach.* 2:393-404.
3. Andrews TM, Price RM, Mead LS, McElhinny TL, Thanukos A, Perez KE, Herreid CF, Terry DR, Lemons PP. 2012. Biology undergraduates' misconceptions about genetic drift. *CBE Life Sci Educ.* 11:248-59.
4. Coley JD, Tanner KD. 2012. Common origins of diverse misconceptions: Cognitive principles and the development of biology thinking. *CBE Life Sci Educ.* 11:209-15.
5. Ware EA, Gelman SA. 2015. The Importance of Clarifying Evolutionary Terminology Across Disciplines and in the Classroom: A Reply to Kampourakis. *Cog Sci.* 39:838-841.
6. Karimi N, Parks BM, Rouse D, Martin K, Dong X, Rajangam PC, Baum DA, Heitz JG. 2017. Building Trees: Introducing evolutionary concepts by exploring Crassulaceae phylogeny and biogeography. CourseSource. <https://doi.org/10.24918/cs.2017.16>.
7. Laidlaw CT, Jensen JL. 2020. Life is just a game: An active learning activity to teach life history evolution. CourseSource. <https://doi.org/10.24918/cs.2020.31>.
8. Butler KJ. 2021. A quick and simple natural selection role play. CourseSource. <https://doi.org/10.24918/cs.2021.10>
9. Nicholson S. 2015. Peeking behind the locked door: A survey of escape room facilities. White Paper available at: <http://scottnicholson.com/pubs/erfacwhite.pdf>
10. Fotaris P, Mastoras T. 2019. Escape rooms for learning: A systematic review. In Proceedings of the European Conference on Games Based Learning. 235-243.
11. Ouariachi T, Wim EJ. 2020. Escape rooms as tools for climate change education: an exploration of initiatives. *Environ Educ Res.* 26:1193-206.
12. Davis D, Lee JG. 2019 June 15. Building Escape Rooms to Increase Student Engagement in First-Year Engineering Classes. In Proceedings 126th ASEE Annual Conference & Exposition. ASEE: Tampa, FL AIP.
13. Alonso G, Schroeder KT. 2020. Applying active learning in a virtual classroom such as a molecular biology escape room. *Biochem Mol Biol Educ.* 48:514-5.
14. Vergne MJ, Smith JD, Bowen RS. 2020. Escape the (remote) classroom: An online escape room for remote learning. *J Lab Chem Educ.* 97:2845-8.
15. Baum DA, Smith SD, Donovan SS, 2005. The tree-thinking challenge. *Science.* 310(5750):979-980.
16. Smith MU. 2010. Current status of research in teaching and learning evolution: II. Pedagogical issues. *Sci & Educ.* 19:539-71.
17. Hoefnagels, M., and Taylor, M.S. 2016. "Boost your evolution IQ": An evolution misconceptions game. CourseSource. <https://doi.org/10.24918/cs.2016.12>
18. Baum D, Jenkins K. 2020. Vertebrate Clade Race (Version 1.0). QUBES. doi:10.25334/D9GX-PC4
19. Goldsmith DW. 2003. The Great Clade Race. *Amer Biol Teach.* 65(9):679-82

Table 1. Lesson Timeline. The lesson best spans two class sessions as well as outside-of-class time for an independent student activity.

Activity	Description	Estimated Time	Notes
Preparation for Class (60-90 minutes)			
Prepare Google Slides for each student group	Create a separate <i>Escape Zoom!</i> Google Slides document for each synchronous student group in your course, and ensure students have access to only their group's slides. This activity also includes granting students who will not be able to synchronously join class on Days 1 and/or 2 access to the appropriate asynchronous Google Slides.	30-60 minutes (depending on size of class)	The template for synchronous student groups' <i>Escape Zoom!</i> activities is provided in Supporting File S3. <i>Escape Zoom!</i> - Synchronous Student Slides (Days 1 & 2). The template for asynchronous students' <i>Escape Zoom!</i> activities is provided in Supporting Files S4 and S5. Asynchronous Student Slides. We would recommend making the Google Slides visible to students right before the start of class on each day. Additionally, this is the step where you can make any necessary adjustments to the pre-established activities based on your specific course learning objectives, student demographics, and class time available.
Edit Instructor Google Slides as necessary	Make edits to the instructor slides and answer key slides to better align this activity with your course learning objectives.	30 minutes	The instructor slides are available in Supporting File S1. Instructor Slides (Days 1 & 2), and the sample (i.e., blank) student response slides with instructor answer key are available in Supporting File S2. Sample Student Response Slides with Instructor Answer Key (Days 1 & 2). In these above files, there are areas for the instructor to tailor the slides for their specific course, including areas to update deadlines, Learning Management Systems, instructor contact information, etc.
Class Session 1 (75 minutes)			
Day 1 Introductory Lecture	Introduce students to the <i>Escape Zoom!</i> lesson guidelines, learning objectives, format, and other logistics. Remind students where to access their group's <i>Escape Zoom!</i> Google Slides link, and to have each completed activity checked by an instructor before proceeding to subsequent activities. Send students to their pre-assigned breakout rooms.	10 minutes	Instructor slides are in Supporting File S1. <i>Escape Zoom!</i> - Instructor Slides (Days 1 & 2).
Activity 1	Students complete Activity 1 (African Cichlid Speciation Case Study) in their groups, and request an instructor to offer feedback on their responses before proceeding.	10 minutes	Synchronous student <i>Escape Zoom!</i> slides are in Supporting File S3. <i>Escape Zoom!</i> - Synchronous Student Slides (Days 1 & 2). The instructor answer key is in Supporting File S2. <i>Escape Zoom!</i> - Sample Student Response Slides with Instructor Answer Key (Days 1 & 2).
Activity 2	Students complete Activity 2 (Phylogenetic Tree) in their groups, and request an instructor to offer feedback on their responses before proceeding.	20 minutes	Synchronous student <i>Escape Zoom!</i> slides are in Supporting File S3. <i>Escape Zoom!</i> - Synchronous Student Slides (Days 1 & 2). The instructor answer key is in Supporting File S2. <i>Escape Zoom!</i> - Sample Student Response Slides with Instructor Answer Key (Days 1 & 2).
Activity 3	Students complete Activity 3 (Mechanisms of Evolution Charades) in their groups, and request an instructor to offer feedback on their responses before proceeding.	10 minutes	Synchronous student <i>Escape Zoom!</i> slides are in Supporting File S3. <i>Escape Zoom!</i> - Synchronous Student Slides (Days 1 & 2). The instructor answer key is in Supporting File S2. <i>Escape Zoom!</i> - Sample Student Response Slides with Instructor Answer Key (Days 1 & 2).

Activity	Description	Estimated Time	Notes
Activity 4	Students complete Activity 4 (Project Biodiversify – Searching for Evolutionary Biologists) in their groups, and request an instructor to offer feedback on their responses.	15 minutes	Synchronous student <i>Escape Zoom!</i> slides are in Supporting File S3. <i>Escape Zoom!</i> - Synchronous Student Slides (Days 1 & 2). The instructor answer key is in Supporting File S2. <i>Escape Zoom!</i> - Sample Student Response Slides with Instructor Answer Key (Days 1 & 2).
Day 1 Wrap-up	Students return to the main Zoom room. Time-permitting, you may ask 1-2 groups to share their charades or Biodiversify activity with the whole class. Lastly, discuss the Day 2 “entry ticket” (i.e., researching COVID-19 mRNA vaccines), and instruct students how they should submit this pre-assignment (if worth additional points beyond the escape room activity).	15 minutes	The prompt for the Day 2 entry ticket can be found on Slide 6 in Supporting File S1. <i>Escape Zoom!</i> - Instructor Slides (Days 1 & 2).
Pre-Assessment (“entry ticket”) for Day 2 (20-30 minutes)			
Pre-assessment for Day 2	Students are asked to individually respond to the prompt regarding COVID-19 mRNA vaccines (Slide 6 of instructor slides) on the LMS discussion board prior to the next class session.	20-30 minutes	The prompt for the Day 2 entry ticket can be found on Slide 6 in Supporting File S1. <i>Escape Zoom!</i> - Instructor Slides (Days 1 & 2).
Class Session 2 (75 minutes)			
Day 2 Introductory Lecture	Remind students of the <i>Escape Zoom!</i> lesson guidelines, learning objectives, format, and other logistics. Remind students where to access their group’s <i>Escape Zoom!</i> Google Slides link, and to have each completed activity checked by an instructor before proceeding to subsequent activities. Send students to their pre-assigned breakout rooms.	5 minutes	Instructor slides are in Supporting File S1. <i>Escape Zoom!</i> - Instructor Slides (Days 1 & 2).
Activity 5	Students complete Activity 5 (Creating a COVID mRNA Vaccines Teaching Slide) in their groups, and request an instructor to offer feedback on their responses before proceeding.	10 minutes	Synchronous student <i>Escape Zoom!</i> slides are in Supporting File S3. <i>Escape Zoom!</i> - Synchronous Student Slides (Days 1 & 2). The instructor answer key is in Supporting File S2. <i>Escape Zoom!</i> - Sample Student Response Slides with Instructor Answer Key (Days 1 & 2).
Activity 6	Students complete Activity 6 (Selecting a Sexual Selection Video) in their groups, and request an instructor to offer feedback on their responses before proceeding.	20 minutes	Synchronous student <i>Escape Zoom!</i> slides are in Supporting File S3. <i>Escape Zoom!</i> - Synchronous Student Slides (Days 1 & 2). The instructor answer key is in Supporting File S2. <i>Escape Zoom!</i> - Sample Student Response Slides with Instructor Answer Key (Days 1 & 2).
Activity 7	Students complete Activity 7 (Escape from Extinction & Deep Space Crossword) in their groups, request an instructor to offer feedback on their responses, and return to the main Zoom room.	20 minutes	Synchronous student <i>Escape Zoom!</i> slides are in Supporting File S3. <i>Escape Zoom!</i> - Synchronous Student Slides (Days 1 & 2). The instructor answer key is in Supporting File S2. <i>Escape Zoom!</i> - Sample Student Response Slides with Instructor Answer Key (Days 1 & 2).
Catch-up	A few extra minutes are scheduled in for student groups who may need additional time to complete Activity 7 and get their responses checked.	5 minutes	

Activity	Description	Estimated Time	Notes
Poll/Review Questions	To review one of the concepts that students tend to struggle with the most in this lesson (i.e., phylogenetic trees), you will ask students to respond to 2 poll questions once all students have returned to the main room. <i>If you planned for this to be a friendly, competitive lesson, this also provides time for one of the instructors to tally points for each student group.</i>	5 minutes	Poll questions and answers are in Supporting File S6. <i>Escape Zoom!</i> – Poll Questions (Day 2).
Activity 8	Students are sent back to their breakout rooms for 1 minute to complete Activity 8 (Speed Round) in their groups. Up until this point, the prompt has been hidden from students.	5 minutes	Synchronous student <i>Escape Zoom!</i> slides are in Supporting File S3. <i>Escape Zoom!</i> - Synchronous Student Slides (Days 1 & 2). The instructor answer key is in Supporting File S2. <i>Escape Zoom!</i> - Sample Student Response Slides with Instructor Answer Key (Days 1 & 2). Activity 8 Speed Round prompt is on Slide 11 in S1. <i>Escape Zoom!</i> - Instructor Slides (Days 1 & 2)
Day 2 Wrap-up	You can answer any remaining questions from students. <i>If you planned for this to be a friendly, competitive lesson, this also provides time for one of the instructors to tally points for each student group and announce a “winner.”</i>	5 minutes	