Microbial Murders Crime Scene Investigation: An Active Team-Based Learning Project that Enhances Student Enthusiasm and Comprehension of Clinical Microbial Pathogens†

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Microbial disease knowledge is a critical component of microbiology courses and is beneficial for many students' future careers. Microbiology courses traditionally cover core concepts through lectures and labs, but specific instruction on microbial diseases varies greatly depending on the instructor and course. A common project involves students researching and presenting a disease to the class. This method alone is not very effective, and course evaluations have consistently indicated that students felt they lacked adequate disease knowledge; therefore, a more hands-on and interactive disease project was developed called Microbial Murders. For this team-based project, a group of students chooses a pathogen, researches the disease, creates a “mugshot” of the pathogen, and develops a corresponding “crime scene,” where a hypothetical patient has died from the microbe. Each group gives a presentation introducing the microbial pathogen, signs/symptoms, treatments, and overall characteristics. The students then visit each other’s crime scenes to match the pathogen with the correct crime scene by critically thinking through the clues. This project has shown remarkable success. Surveys indicate that 73% of students thought the project helped them understand the material and 84% said it was worth their time. Student participation, excitement, understanding, and application of microbial disease knowledge have increased and are evident through an increase in course evaluations and in student assessment scores. This project is easy to implement and can be used in a wide variety of biology, microbiology, or health classes for any level (middle school through college).

INTRODUCTION

Allied health and general microbiology students are often taking microbiology courses because they are pursuing a career in health care. For many of these professions, microbial pathogens and the diseases they cause will be a routine responsibility of the job. Despite microbial diseases being a major part of the students' future career, often lectures and labs are focused on core microbiology concepts and the disease units are left to be covered in a variety of ways depending on the instructor and course (1). Students have traditionally prepared presentations on a single disease and taught the class while the other students passively listened. These disease presentations were not very effective, and students regularly reported only learning/retaining knowledge about their own presentation (despite quizzes, final exam questions, and bonus points used as bribery to listen and learn from the disease presentation).

Evidence has shown that active learning and creating or synthesizing something is a great way to learn (2,3). Case studies are well accepted for being valuable educational tools to help students see real-world connections and applications to microbiology (4–6). Additionally, there is significant value in team-based learning and working as a group to develop a final project (7–9). In an effort to combine these successful educational elements with our microbial disease projects, we developed a project called Microbial Murders: A Crime Scene Investigation. This project involves research, collaborative group work, presentations, peer-teaching, creativity, synthesis of a crime scene, and critical thinking to apply previous knowledge to solve and identify the microbial murder suspects at crime scenes designed by fellow students. Essentially, students work in teams to design a crime scene (similar to writing a case study, but they have to make a scene and bring the case study to life). In Microbial Murders: A Crime Scene Investigation, students sign up to be in groups based on a disease of interest. Each of the diseases will be responsible for killing a hypothetical person at the given crime scene. The project is presented to the students, and the groups then work together to research their microbial pathogen. Each group prepares a “mugshot” of their microbe, a presentation that will be used in the “debriefing” meeting to teach other students about the microbial pathogen.
The group then prepares a crime scene, where someone has fallen victim to the microbial pathogen. During the "debriefing" meeting, each group presents their microbial pathogen suspect by showing the microbe's "mugshot" and presenting basic facts about the disease (signs, symptoms, etiology, demographics, geography, diagnosis, treatment, prevention, etc.). Students listening to the presentations can take notes, which they can use in solving the crime scenes. Once all of the microbial murder suspects have been presented, the students participate in identifying which crime scene corresponds with which pathogen. Each crime scene is developed by the students and must include significant clues to identify the responsible microbe. Clues include storyline and background information about the patient as well as clinical and lab tests, leading to a correct diagnosis and identification of the microbial murderer. Students have thoroughly enjoyed this activity, and learning outcomes have been measured and indicate that this activity increases student comprehension and understanding of microbial diseases. This exciting project is a great way to cover microbial disease pathogens using a team-based, active learning method that requires students to create clues and have a mastery of key facts and elements of microbiology disease diagnosis and treatment.

Intended audience

This Microbial Murders: A Crime Scene Investigation project was designed for undergraduate courses, in particular the sophomore level Introduction to Microbiology course required by our nursing program and other allied health majors and programs. However, we regularly have nonmajors and majors in this course who take it for elective credit, and this project has been well received by a wide variety of audiences. This has been implemented in a lecture and lab course that students take concurrently, but it could be used in either the lecture or the lab along.

Prerequisite student knowledge

Students need basic biology knowledge to complete this activity. Although not required, previous exposure to crime scene investigation media/ideology will help students formulate clues and design a crime scene. Specific details and examples are utilized during the introduction of this project that help students grasp the big picture and favor their success. As we go through lecture and discuss specific microbiology core concepts (gram stain, culture media, signs/symptoms, control/treatments, immune response, etc.), specific comments can be made that will be beneficial in designing their crime scene.

Learning time

This project is implemented as a whole-semester final project. Students choose groups early on in the semester and work throughout the semester (outside of class) to prepare the final presentation and crime scene. We take two (50-minute) class periods at the end of the semester for group presentations in our "debriefing" meeting on the microbial pathogens and then a third class period is used for solving the crime scenes (during the lab component of the class, which is 105 minutes).

Learning objectives

Upon completion of this project, students will be able to:

1. Assemble core microbiology and pathogen knowledge into clearly designed clues and evidence leading to a particular microbial disease.
2. Examine and analyze other students' clues and scenes in order to critically identify the corresponding pathogen.
3. Explain and describe the impact of microbial pathogens on human health and differentiate specific details for a wide variety of common microbial diseases.

Assessment of student learning outcomes through post-participation surveys has indicated student enthusiasm, excitement, and appreciation for this project. Data and scores on a microbial pathogen disease quiz indicate that those participating in the crime scene investigation comprehend significantly more about the microbes than those just listening to presentations. Additionally, scores on their final unit exam (covering microbial diseases) have increased since the implementation of this project.

PROCEDURE

Materials

Students will need access to research materials (printed or online) to research their microbial disease pathogen. They will need to create an original "mugshot" of their pathogen, which is often done on the computer (using POWERPOINT, PAINT, PHOTOSHOP, ILLUSTRATOR, or other software) or using art supplies to paint or draw the microbe. Additionally, students will need to create clues and evidence to be displayed as part of their "crime scene." These supplies vary depending on the disease and group, but it is left to the students to identify and create the clues. All the handouts and rubrics that are needed to implement this project are included in the supplementary materials.

Student instructions

Students should read the Microbial Murders handout (Appendix 1). During the first week or two of the semes-
ter, students will be able to sign up for a disease, choosing
the one that is most interesting to them. This project is
team-based because increasing evidence shows the benefits
of working as a team or group in helping students learn
(8–10). These student teams are usually three to four
students. The list of disease options varies each semester
depending on what the instructor feels is important and
also based on course enrollment, but some that have been
used in the past include malaria, HIV, MRSA, Rabies,
C. difficile, botulism, tuberculosis, measles, pertussis, influenza,
cholera, and polio. Once in a disease project team, each
group will be responsible for researching their microbial
disease and producing the following three components:

1. A presentation for the “debriefing” meeting. This is
similar to a traditional disease presentation, where
students stand up and report on the common facts
and statistics pertaining to a certain microbial dis-
eease. A great way for a student to learn is to teach
their peers, and this project provides the students
with the opportunity to teach their fellow students
about their disease (9,11,12). Each group has about
eight to ten minutes to introduce their microbial
pathogen. The groups are aware of their own clues
and can tailor their presentations to include the
information that the other students will need to
successfully solve the crime scene.

2. An original mugshot of the microbe, which can be
anthropomorphic and include specific hints or details
pertaining to the microbe (Gram positive bacteria
are often depicted as wearing or being colored
purple). Often students have a hard time under-
standing and relating to the microbes; this activity
provides a visual representation of the pathogen
that helps students remember the pathogen and key
facts, similar to what has been accomplished using
plush microbes as teaching tools (13).

3. A crime scene, with evidence and clues pertaining
to a victim that was infected with their pathogen.
These clues are meant to require critical thinking
and mastery of microbiology concepts. Case stud-
ies are great ways for students to see applications
and real-life context for microbiology concepts
(5,6). This is similar to creating a case study, but
they have to bring their case study to life and cre-
ate an actual crime scene. There must be at least
five clues that point to the etiology, transmission,
demographic, geography, signs/symptoms, diag-
nosis, treatment, or prevention of the disease.
In addition, at least two clues must be lab-based,
such as Gram stain results, images taken under a
microscope, blood tests, white blood cell counts/
populations, etc. These clues are designed and
developed by the students in the group. The clues
can be presented using a variety of mechanisms,
including hands-on, digital, printed pictures, etc.

They can be organized in a “box of evidence from
the crime scene,” or students may choose to set
up the actual crime scene. Students are presented
with some ideas and examples (Appendix 2), but
for the most part, it is left open-ended to allow
for creativity, personalization, and ownership
of the project. Some students have made elaborate
videos to present the crime scene; others have
made simple posters with all the clues. They are
graded most heavily on content and quality/ac-
curacy of the clues, but some points are given for
creativity and students can vote on their favorite
crime scene for a few extra credit points.

Faculty instructions

The best part of this project is that the students do all
the work for preparation and set up. Examples are shown
the first week of class (Appendix 2), but other than that, the
students do most of the work within their groups. Specific,
in-class work days or time for working on the project are
not explicitly designated in the course, but occasionally
if there is extra time during a lecture or other activity,
the students can assemble and discuss the status of their
project. It has been noted that if groups can get together
at least a couple times during class, it helps the overall
progression of their project, gives them thinking about it,
and allows for the groups to ask for help or clarification
from the instructor (6).

The Microbial Murders: A Crime Scene Investigation
project involves three main components (as introduced in
the student instructions section): a presentation, a mugshot,
and a crime scene. The presentations are similar to what
has been used in traditional disease presentations, but
the utility and context of the microbial murders seems to
make the presentations more exciting and relevant. These
presentations are initiated by the instructor standing up
and welcoming the students to the “debriefing” meeting. A
game announcement is made that there have been X num-
ber of fatalities (based on the number of disease teams for
the particular semester). The instructor then continues to
introduce the presentations by saying that the students will
have the opportunity to learn about the potential microbial
murderers and that it is their job to help identify the cause
of death. It is advised that the students pay attention and
make notes, which will help them correctly solve the crime
scenes. This introduction really gets the students excited
to learn and to listen. The students take notes and ask
questions because they know that they will have to apply
this knowledge in a very real setting. Depending on the size
of the class, these presentations can be done in a group
for the whole class (peer or instructor graded, Appendix
8), or the teams can divide up with a representative from
each disease in a group and present the microbial suspects
in a smaller setting, in which case the presentation is peer-
graded (10,11).
For the mugshot portion of the project, students are provided with the rubric and shown an example. The instructor can require the mugshots to be turned in prior to the presentations, or they can be premiered during the debriefing meeting. After the presentations, the instructor collects the mugshots and will display them at the front of the classroom during the solving of the crime scenes.

The crime scene can be the most difficult part of the project for the students. For the most part, students understand the premise of the project and are enthusiastic about it (compared with writing a paper or a presentation alone). The hardest part for them is coming up with valid and difficult clues. I offer to sit down with each group and discuss their ideas and help them with the clues. Students are given a list of suggested or previously successful clues (Appendix 2), which can be very beneficial. The clues can be displayed all at once at their crime scene or they can be available in a sequential manner (start with clue #1 and then proceed to #2 and so on). For solving the crime scenes, a room is reserved in advance (either the usual classroom or another room, based on availability for set up time prior to class). The room is then prepared with different scene numbers spread around the room (e.g., scene #1 at the front by the board, scene #2 against the wall, and so forth). The groups are responsible for setting up their own crime scenes, and a sign-up sheet is available with the instructor for the groups to have access to the room and set up without other groups around. The sign up is kept anonymous so groups won’t be tipped off by which groups are ahead of them and which crime scene numbers are already set up. Once all the crime scenes are set up, the mugshots can be posted at the front of the classroom, and the solving can begin. Groups work together to solve the scenes and can work at their own pace, but they cannot be at the same scene as another group. Each group has to return everything and re-set up the crime scenes before they are done with a particular scene. The groups are given a worksheet (Appendix 4) for solving the crime scenes. They match the crime scene with a particular microbe, and they also fill out questions pertaining to what could have been done to prevent or treat this disease. Finally, they vote on their favorite crime scene and turn in the handouts once they have solved all the crime scenes. These handouts are graded, and the favorite crime scenes are counted and extra credit points are given. Students stay until the end and are responsible for cleaning up their own crime scene.

Sample data

An example of some mugshots and crime scenes can be seen in Figure 1. However, the variety of crime scenes and mugshots has been very diverse; those illustrated in Figure 1 are just an example. For a full list of clue ideas and successful scenes from previous semesters, please see Appendix 2.

Safety issues

There are no safety issues with this project. Students should be advised not to use real samples or clues in their crime scenes.

Suggestions for determining student learning

Student learning has been assessed using a variety of different methods. A microbial disease quiz (Appendices 5 and 6) is given following the “debriefing” meeting to measure the level of understanding gained from presentations alone. A similar disease quiz is then given following solving the crime scenes and can be used to measure the learning gains that occur due to solving the crime scenes. This disease quiz partially helps assess learning objective (LO) 3 to measure the students’ comprehension of microbial pathogens. In addition to the disease quiz, more open-ended essay questions are included in the unit 4 and final exams that can be used to measure learning gains. The “Solving the crime scene” worksheet (Appendix 4) is a valuable tool for assessing how well the groups do at analyzing and critically thinking through the clues. Each group works on a single worksheet that they take from scene to scene. Students demonstrate their comprehension by correctly identifying the microbe responsible for the crime scene as well as describing what could have been done to prevent or treat the disease. Students’ responses on the “Solving the crime scene” worksheet can be used to assess LO2. The crime scenes are graded using the rubric (Appendix 3) and can also be used to measure the level of comprehension of the responsible group based on the quality and depth of thinking required to solve the clues (LO1). Performance on the corresponding unit exam and/or final exam has also been used as a metric to assess the efficacy of this disease project.

FIGURE 1. Examples of microbial mugshots and crime scenes.
DISCUSSION

Field testing

The Microbial Murders: A Crime Scene Investigation has been used in a sophomore level undergraduate introduction to microbiology course that is required for the nursing and allied health programs. It was implemented in a lecture/lab combination course where the debriefing meetings were held during lecture and solving the crime scenes occurred during lab time. However, this can be adapted for use in lecture-only or lab-only classes. This project has been implemented for three different semesters in the same 200-level introduction to microbiology course, and the enrollment has varied from 45 to about 25 students. In order to have enough crime scenes, eight to twelve different diseases are available for students to work with, making group sizes anywhere from two to five students (preferentially three or four students per group, but with students withdrawing and other issues, the group sizes have been between two and five). Students’ response to this project has been great. In an end-of-semester survey that asks students for their personal and unbiased opinion on different aspects of the course, over 85% of students said that this project helped them understand the material (Fig. 2) (Appendix 7) (responses represent the average of three semesters with a total of 89 students answering survey questions). A total of 87% of students said that it was worth their time and that they enjoyed it, and 75% of students adamantly stated that they should not be dropped from the course. (This 3rd question serves as an internal survey control to ensure students are not just checking “yes” to complete the survey.) These survey results indicate student perceptions of their own understanding of the material and illustrate overall attitude and enthusiasm for this project. It is very well received, and students are very excited to show off their crime scenes and solve their peers’ scenes. In addition, students’ participation in and attention to the disease presentations are much higher when they know that they will have to solve a crime scene using the information they are learning (personal observation). Students were anxiously listening and taking notes during the presentations, which was remarkably different from when they did passive disease presentations without the microbial murder/crime scene context. This project has been implemented by several other instructors at various institutions and campuses, and all have reported similar results, with an increase in student enthusiasm and comprehension of microbial diseases.

Evidence of student learning

The efficacy of this project in meeting the suggested learning objectives can be assessed using an analysis of student performance on the crime scene preparation, solving the scenes, and grades on the relevant quizzes and exams. LO1 states that students will be able to “assemble core microbiology and pathogen knowledge into clearly designed clues and evidence leading to a particular microbial disease.” To assess LO1, we can look at the scores from the grading of the crime scenes (see rubric in Appendix 3). From three semesters worth of data (comprising 26 groups and 90 students), 23 groups got above a 90% on the crime scene preparation, 2 groups had a score of 80 to 89%, and only 1 group received below 80% (Fig. 3). This aligns with LO1 and indicates that 88.5% of teams were able to successfully create the desired quality of crime scene clues and evidence. Groups needed different levels of support and guidance for preparing crime scenes, but in the end, they demonstrated significant knowledge and ability to complete LO1 and create some very fascinating crime scenes.

Assessment of LO2, the ability to examine and analyze clues and scenes to critically think and identify the corresponding pathogen, can be measured using the scores achieved by groups trying to solve the crime scenes (see rubric and worksheet in Appendix 4). Of the 26 teams, 21 (80.8%) were able to correctly identify 100% of the crime scenes and answer the questions on the worksheet correctly (Fig. 3). Two teams scored in the 90% range and two teams had scores near 80%. This indicates that students were able to accurately analyze the clues and determine the corresponding pathogen, aligning directly with LO2.

LO3, “explain and describe the impact of microbial pathogens on human health and differentiate specific details for a wide variety of common microbial diseases,” is more complex and difficult to assess. To measure student learning gains, specific data were gathered from disease quizzes (Appendices 5 and 6) administered following the debriefing meeting but prior to solving the crime scenes (indicated as “Pre” solving) and from similar quizzes administered after solving the crime scenes (indicated as “Post” solving). Results indicate that students understand considerably more about microbial diseases following solving the crime scenes. A 12% increase in the disease quiz average is seen post-solving, with nearly 75% of students performing better on the quiz.
after solving the crime scenes (Fig. 4). (Data represent an average of three semesters worth of assessment involving 90 students.) This disease quiz assessment aligns with LO3 and can be used to measure student learning gains from the activity. Additionally, Unit Exam scores or questions from the final exam can be used to measure learning gains achieved by participating in this activity. Each semester, several students choose to only enroll in the lecture part of the course and not the lab and therefore receive the disease information as a presentation only, but they do not participate in solving the crime scenes. Analysis of student exam scores and data from those who did not participate in solving Microbial murders, compared with those who did, indicate a significant improvement on the unit and final exams for students who participated in the Microbial Murders: A Crime Scene Investigation project (Fig. 5). (Data represent the average of three semesters, with a total of 101 students, 90 of whom solved the crime scene and 11 of whom did not.) Overall, student enthusiasm for and comprehension of microbial diseases has increased since the implementation of the Microbial Murders: A Crime Scene Investigation project. The attached resources are available, and additional questions or ideas can be directed to the author.

Possible modifications

This project has great potential to be applied in a variety of different courses and institutions. It could be modified for medical microbiology, infectious disease, public health, or general microbiology courses. In addition, this could
be applied to middle or high school science classrooms to implement a microbial disease unit.

SUPPLEMENTAL MATERIALS

Appendix 1: Microbial murders disease project handout
Appendix 2: Examples of crime scene clues and scenes
Appendix 3: Mugshot and crime scene grading rubric/score sheet
Appendix 4: "Solving the crime scene" worksheet
Appendix 5: Disease quiz question bank
Appendix 6: Disease quiz question answer key
Appendix 7: End-of-semester student survey
Appendix 8: Peer review disease teaching rubric/score sheet

ACKNOWLEDGMENTS

The author received a curriculum development grant from the Center for Teaching and Learning (CTL) at CSU-Pueblo that provided some funding to support this project. Heidi Smith at Front Range Community College (Fort Collins, CO) was very helpful for brainstorming and discussing the ideas and assessment of this project. Joyce Davis at Carroll Community College (Westminster, MD) also provided great feedback and suggestions as she implemented the project at her institution. The authors declare that there are no conflicts of interest.

REFERENCES