

Enhancing Student Learning on Emerging Infectious Diseases: An Ebola Exemplar

DEREK DUBE, TRACIE M. ADDY, MARIA R. TEIXEIRA, LINDA M. IADAROLA

ABSTRACT

Throughout global history, various infectious diseases have emerged as particularly relevant within an era. Some examples include the Bubonic plague of the fourteenth century, the Spanish Influenza pandemic of 1918, the HIV epidemic of the 1980s, and the Zika virus outbreak in 2015–16. These instances of emerging infectious disease represent ideal opportunities for timely, relevant instruction in natural and health science courses through case studies. Such instructional approaches can promote student engagement in the material and encourage application and higher-order thinking. We describe here how the case study approach was utilized to teach students about emerging infectious diseases using the 2014–16 Ebola virus outbreak as the subject of instruction. Results suggest that students completing the case study not only had positive perceptions of the mode of instruction, but also realized learning gains and misconception resolution. These outcomes support the efficacy of case pedagogy as a useful teaching tool in emerging infectious diseases, and augment the paucity of literature examining Ebola virus knowledge and misconceptions among undergraduate students within United States institutions.

Key Words: Ebola virus; emerging infectious disease; virology; case study; student misconceptions.

○ Introduction

In 2014, the largest Ebola virus outbreak in recorded history began in West Africa and lasted nearly two years, with 28,652 cases (suspected, probable, and confirmed) and 11,325 deaths, as reported by the Centers for Disease Control and Prevention (CDC, 2016). Although centered in the West African countries of Sierra Leone, Liberia, and Guinea, individuals in seven additional countries on three continents, including the United States of America, were also infected with Ebola virus. As this deadly virus quickly became an epidemic, news agencies were quick to broadcast the devastation. Reports caused public concern over the spread of the pathogen, and were often devoid of biological explanations. Valuable teaching

opportunities arose to promote scientific understanding, as well as to combat misconceptions. Many of these efforts targeted citizens in regions outside of the United States (Shittu et al., 2015; CRS, 2014). However, a paucity of research was focused on American understanding of the Ebola virus. There have also been limited efforts to date directed at undergraduate students and their understanding of Ebola virology and misconceptions (Miller, 2016).

An overarching aim of this work was to provide insight into promising strategies for teaching college students about emerging infectious diseases generally, and the Ebola virus in particular, to foster learning and to address misconceptions. The case study approach is particularly amenable to this work and has shown to be efficacious in both science and non-science fields (Bonney, 2015; Breslin & Buchanan, 2008; Herreid, 2013; Krain, 2016). Case-based methods often employ active learning in the form of collaborative work. Active learning essentially encompasses any instructional method that engages students in the learning process, and can come in a variety of forms. Such approaches have been shown to increase student performance on examinations and decrease failure rates in science, technology, engineering, and math (STEM) fields (Freeman et al., 2014).

In this study, we examined the specific impacts of a case study on student learning about the Ebola virus. Three research questions guided this investigation: How do students perceive their learning about the Ebola virus through the published case? Do students show significant learning gains after completing the case? Does completing the case resolve existing student misconceptions about the Ebola virus?

To address these questions, *The Ebola Wars: General Edition* (Addy et al., 2016) was used as a model case study focusing on a relevant emerging infectious disease, and implemented in an undergraduate microbiology course serving both natural and health science majors. This case, published in the National Center for Case Study Teaching in Science Database, scaffolds students into learning the major attributes of viruses and their life cycles, and delves deeper into the biological features of the Ebola virus. Instructors can freely use the published case in their classrooms. We describe here the outcomes of our

research on student perceptions, misconception resolution, and learning via the case.

○ Method

Participants

Participants included 32 female natural and health science major undergraduate students enrolled in an introductory microbiology course in a private university in the northeast United States. Approximately two-thirds of the students were nursing majors, and the majority of the remainder were biological science majors.

Design and Procedures

Case Study Design

Using a storyline with a main character and probable scenario of infection, *The Ebola Wars: General Edition* supports student learning of the general attributes of viruses, and application of their general knowledge of virology to the specific biological features of the Ebola virus. The case uses a stepwise approach to guide students in understanding:

- What are viruses?
- What are the structural features of viruses, and how are they related to their function?
- How do viruses infect host cells and utilize host cell machinery to reproduce?
- What are the major structural features of the Ebola virus?
- How does the Ebola virus enter host cells and reproduce?
- What treatment options were available during the 2014 outbreak? and
- What treatment option is most efficacious for the main character of the case?

Advanced courses with students who have extensively studied general virology and lifecycles can use the Parts I, II, and III of the case for review. Introductory courses may devote more time to the beginning sections of the case to encourage foundational learning. Revision of the main character and storyline for context, as well as the latter portions of the case to focus on the biological attributes of a different virus, allow this case framework to be adapted for other infectious diseases.

Case Study Implementation

The case was implemented in a microbiology course serving natural and health science majors. All research was approved by the Institutional Review Board, and participants provided informed consent. Student perceptions were evaluated after completing the case, and pre- and post-instruction knowledge assessments were administered. Prior to the employment of this case, the students were introduced to some general virology concepts such as obligate requirement for a host, common structures, and replication stages. As an out-of-class assignment, students were provided Parts I–III of the case, which introduce the scenario and main character of the case and review general virology concepts. They were asked to read and answer the relevant questions prior to class. In class the next day, the instructor led with a ten-minute contextual discussion with the students about the Ebola virus, focusing on the epidemiology of historical and recent outbreaks (Appendix I). This

was followed by an instructor-prompted, but student-led, discussion and overview of Parts I–III of the case. The remainder of the case study (Parts IV, V, and VI) was then distributed, and the balance of the class session (approximately thirty minutes) was organized in an interrupted fashion, where students read a single part, then worked in small groups (two to five students) to answer the provided questions before coming together as a whole class for a brief discussion, and moving onto the next part of the case. After the case was completed, the class came together one final time, and the instructor led a wrap-up discussion, aimed at focusing on the major “take-home message” of the case and its relatability to other infectious diseases. Additional details for future implementations can be found in the Teaching Notes published with the case at the National Center for Case Study Teaching in Science.

Measures

Student Perceptions Survey. Immediately following instruction, students responded to a twenty-nine-question survey regarding their perceptions of learning with the case on a five-point Likert scale. Possible responses included: “Strongly Agree,” “Agree,” “Neutral,” “Disagree,” “Strongly Disagree,” and “N/A.” The class data was then compiled and analyzed.

Pre-/Post-Assessment. The efficacy of the case study in supporting student learning was assessed through pre- and post-knowledge assessments. The pre- and post-knowledge assessment consisted of ten identical questions in varying format and Bloom’s Revised Taxonomy levels, covering diverse content from the case. The specific questions used can be seen in Appendix II.

The pre-assessment was administered in class immediately prior to the case study being provided and Parts I–III assigned, and the post-assessment was included in the students’ standard course examination approximately two weeks after the instruction. The students were not aware that the questions from the pre-assessment would be present on their post-assessment, nor were the questions and answers returned to the students during the intervening time. The resulting data were analyzed by raw score on a question-by-question basis, as well as for normalized learning gains.

○ Results

Student Perceptions

In general, the students found both the material and the manner in which the material presented to be interesting (97%), with only one student of thirty-two disagreeing with these statements (Figure 1). Additionally, 53 percent of responding students indicated that they enjoyed using the case study to learn about the Ebola virus, 28 percent were neutral, and only 19 percent did not like this method of learning. Moreover, 63 percent of students stated that this instructional method aided their critical thinking broadly about virology and human health, and 75 percent of students responded that it aided in their critical thinking about the Ebola virus, specifically. As relevant to this study focused on teaching about recent and current emerging infectious diseases, 94 percent of students indicated that the instructional method “clearly connected the material to its effect in the real world.”

With regard to student perceptions of learning, 83 percent of the respondents “agreed” or “strongly agreed” with the statement, “Prior to the class session, I did not know much about Ebola virus.” Only 22 percent of the respondents disagreed with the statement,

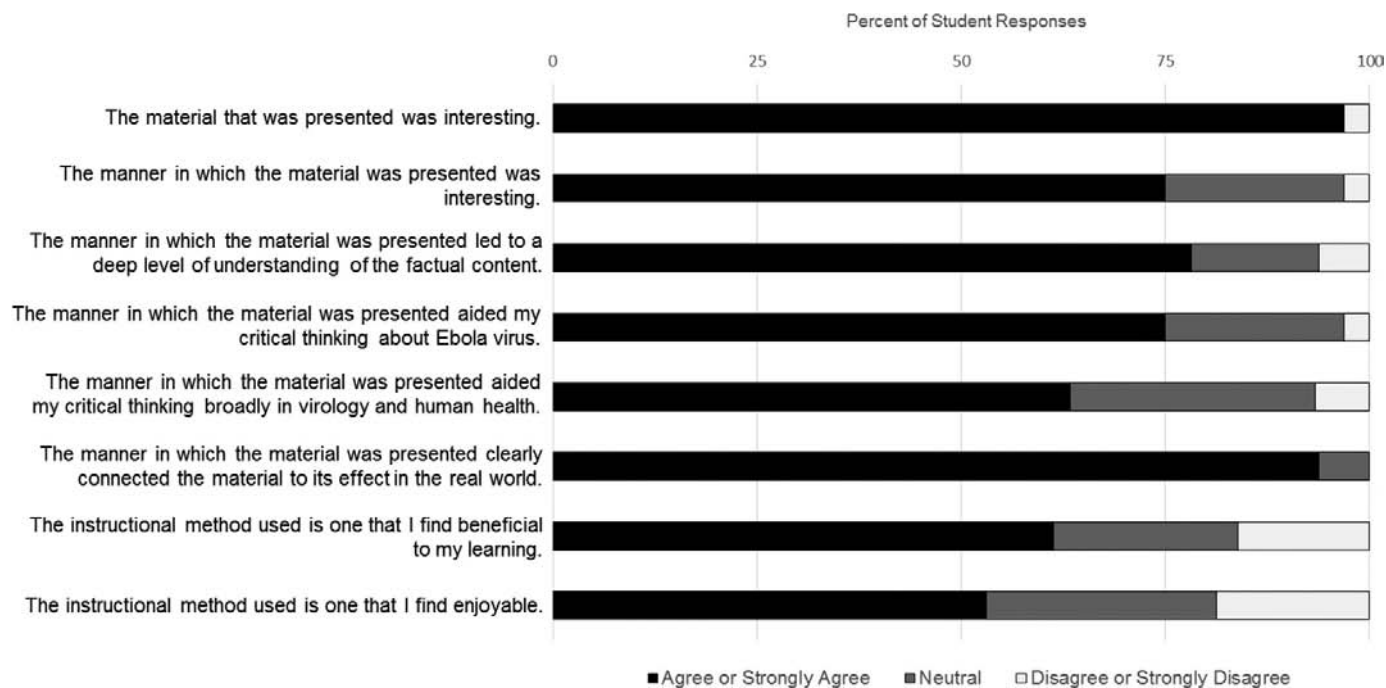


Figure 1. Student perceptions of the case study teaching methodology ($n = 32$).

Table 1. Student perceptions of general learning gains and resolving misconceptions about the material through *The Ebola Wars: General Edition* case study (Addy et al., 2016) ($n = 32$).

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Prior to class session, I did not know much about the Ebola virus.	0%	0%	19%	67%	15%
After the class session, I am knowledgeable about the Ebola virus.	0%	22%	38%	31%	9%
Prior to the class session, I had misconceptions about the material.	0%	0%	13%	47%	41%
After the class session, my misconceptions were remedied.	0%	13%	22%	38%	28%

“After the class session, I am knowledgeable about Ebola virus” (Table 1). When asked questions about how students perceived their learning about specific concepts and acquiring specific skills relevant to the stated learning objectives of this instruction, the response was overwhelmingly positive. Across all thirteen questions, in no case did more than 17 percent of students not feel confident that they could accomplish the stated goals (Figure 2). Indeed, for several learning objectives (five of thirteen), over 90 percent of students responded positively that they were confident in their abilities and/or knowledge after the instruction, and none were below 53 percent. Collectively, these data suggest that most students enjoyed completing the case study and perceived that it benefitted their learning.

Student Learning Gains

Consistent with the perceptions data, students exhibited significant learning gains after the case, as evidenced by their scores on

identical question sets pre- and post-instruction (Figure 3). On all questions, average correctness improved after instruction with the case (Figure 3A). Further, on eight of the ten questions, the normalized learning gains were over 50 percent, with an overall normalized learning gain of 63.2 percent (Figure 3B). The normalized learning gains capture the percentage of the material that the students did not know prior to the case study and were able to answer correctly after instruction. Such learning gains were relatively consistent on questions from all levels of Bloom’s Revised Taxonomy, including those requiring higher levels of critical thinking (Appendix II and data not shown).

Misconception Resolution

Two common Ebola misconceptions were also examined directly in this study (Appendix III) (Miller, 2016). The first was the etiological agent that causes the disease (e.g., bacteria, virus, protist, etc.) addressed in Question 1, and the second was the misconception that

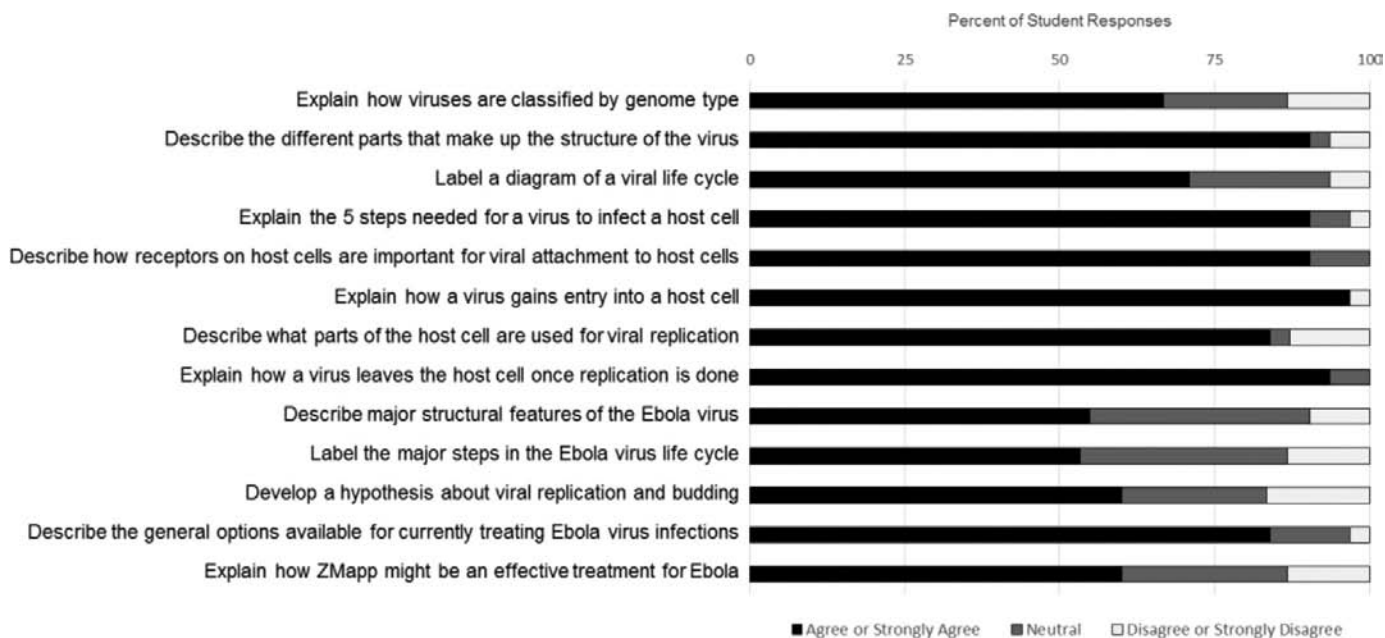


Figure 2. Student perceptions of learning objectives achieved ($n = 32$). This group of questions was preceded with the question stem, “After the Ebola virus–related instruction on the date indicated, I feel confident that I could. . .”

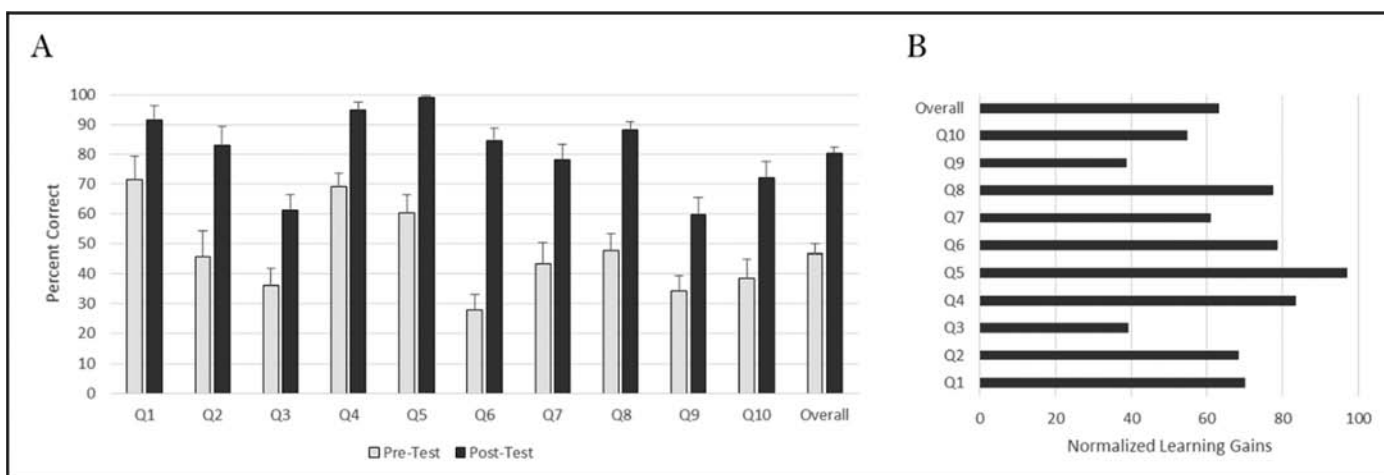


Figure 3. Student learning gains as assessed by pre-instruction assessment and post-instruction assessment with an identical question set. The questions and their assigned Bloom’s Revised Taxonomy categorization can be seen in Appendix II. **(A)** The average correctness for each question asked and overall for all students ($n = 32$), both before and after instruction. Error bars represent standard error. **(B)** Normalized learning gains for each question and overall, as determined by the equation: $100 \times [(post\text{-}test - pre\text{-}test) / (100 - pre\text{-}test)]$

human-disease-causing Ebola virus can be spread through the air addressed in Question 2. In this cohort of biology and health science majors, before instruction, 29 percent of students were unable to properly identify Ebola as an “RNA virus” and 54 percent incorrectly believed the disease could be spread from human-to-human through the air (Figure 3A). After instruction, the rate of these misconceptions dropped significantly to 9 percent and 17 percent, representing normalized learning gain scores of 70 percent and 68 percent, respectively (Figure 3A and 3B).

Additionally, a general misconception related to the definition of a virus as a living or non-living entity (Miller, 2016) was

examined tangentially in Question 3, which asked the students why the Ebola virus particle is not considered a cell. There was a normalized learning gain of 39 percent for this short-answer question (Figure 3B). Further, Question 4 was an open-ended question that asked students why the Ebola virus is categorized as a Class A Priority Pathogen, which, depending on the student answer, could address noted misconceptions about the mode of transmission, incubation period, mortality rate, and treatment options specific for Ebola virus (Appendix III) (Miller, 2016). Qualitatively, answers in the post-assessment showcased a more accurate understanding of these features, and quantitatively, average correctness increased

from 69 percent to 95 percent between pre- and post-assessment, representing a normalized learning gain of 83 percent (Figure 3A and 3B).

As an additional means of assessing misconception resolution through this pedagogy, students were asked relevant questions in their Perceptions Survey. Of the respondents, 88 percent “agreed” or “strongly agreed” with the statement, “Prior to the class session, I had misconceptions about the material,” and the majority of the respondents, 66 percent, “agreed” or “strongly agreed” that working through the case helped resolve their misconceptions about the Ebola virus (Table 1).

○ Discussion and Implications

In this study, implementation of the case study approach in teaching about a relevant and emerging infectious disease yielded significant pre-/post-learning gains, and was received favorably by the students. Indeed, our work shows that *The Ebola Wars: General Edition* case can be effective at resolving student misconceptions about the Ebola virus and the disease it causes, and suggests that this pedagogical design in general may be useful in accomplishing similar goals for other emerging infectious diseases. To this end, instructors can build on the framework of the published case to support student learning about other infectious diseases, relevant to the time of instruction and enhancing biological knowledge beyond what is learned from the media or other sources. Specifically, as Parts I–III focus on concepts in general virology, only minor changes made to the main character’s storyline would be necessary, maintaining much or all of the biological information and student questions intact. Then Parts IV, V, and VI could progress through the morphology, life cycle, treatment options, and disease outcomes relevant to the virus of choice. The particular infectious disease to feature would be dependent on the global health situation at the time of instruction, but emerging viruses and those causing significant outbreaks, such as HIV, influenza, and Zika, may make for particularly impactful selections.

There are several extensions to this study that could provide interesting and important data. As this study included exclusively female participants at a private university, in the future it would be informative to conduct studies extending the findings of this work to examine if distinct demographics (e.g., gender, geographical location, underrepresented ethnicities, first-generation status, etc.) experience differences in learning gains and perceptions of the pedagogy generally, and this case, specifically. In future implementations, to more fully explore student misconceptions about the Ebola virus prior to instruction, the Virus and Ebola Misconceptions Assessment (VirEMiA) (Miller, 2016), which was still in the process of publication during this study, could be completed by the students. Additionally, a direct comparison of lecture-based pedagogy covering identical content as the case would provide further evidence regarding the efficacy of the case study itself. Also, examining whether completing this case led to students having improved critical thinking skills regarding distinct topics within the field of the biological sciences would be insightful to the broader impacts of this pedagogy. Finally, exploring ways that case-based learning on emerging infectious diseases can be integrated within course-based research experiences is an area of interest.

Overall, when combined with past studies examining case study pedagogies used to teach in distinct content areas (Bonney,

2015; Breslin & Buchanan, 2008; Herreid, 2013; Krain, 2016), our work provides insight into pedagogy that supports student scientific literacy. Specifically, this study also examines the prevalence of misconceptions about the Ebola virus (in the undergraduate cohort the United States) and identifies an effective means to address these misconceptions, an area that is lacking in the literature (Miller, 2016).

○ Acknowledgements

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Appendix I

The following is an outline of the topics addressed during the in-class contextual discussion of Ebola virus (prior to directly discussing the case study itself). This outline may be used by instructors to create a set of slides for presentation complete with the most up-to-date information, as well as to serve as prompts for the development of discussion questions. The official websites for agencies such as the Centers for Disease Control and Prevention and the World Health Organization serve as ideal sources for current accurate information.

- Description of historical outbreaks (including geography, associated mortality, and viral strains involved)
- Description of the 2014–16 Ebola outbreak (or the most recent outbreak) including aspects that made it unique (presence in areas of increased population density, international travel, etc.)
- Description of enzootic and epizootic transmission cycles
- Description of modes of human-to-human transmission
- Description of incubation time, symptom progression, and mortality rates (can be compared to other infectious diseases)
- Commentary on the current state of treatment

Appendix II

The question set below was given to the students both as a pre-assessment, prior to seeing the case, and as a post-assessment, embedded within their planned course exam, approximately two weeks after completing the case. The question numbers are aligned with those presented in Figure 3. The most appropriate categorization using Bloom's Revised Taxonomy is indicated in parentheses after each question.

Instructions for Students

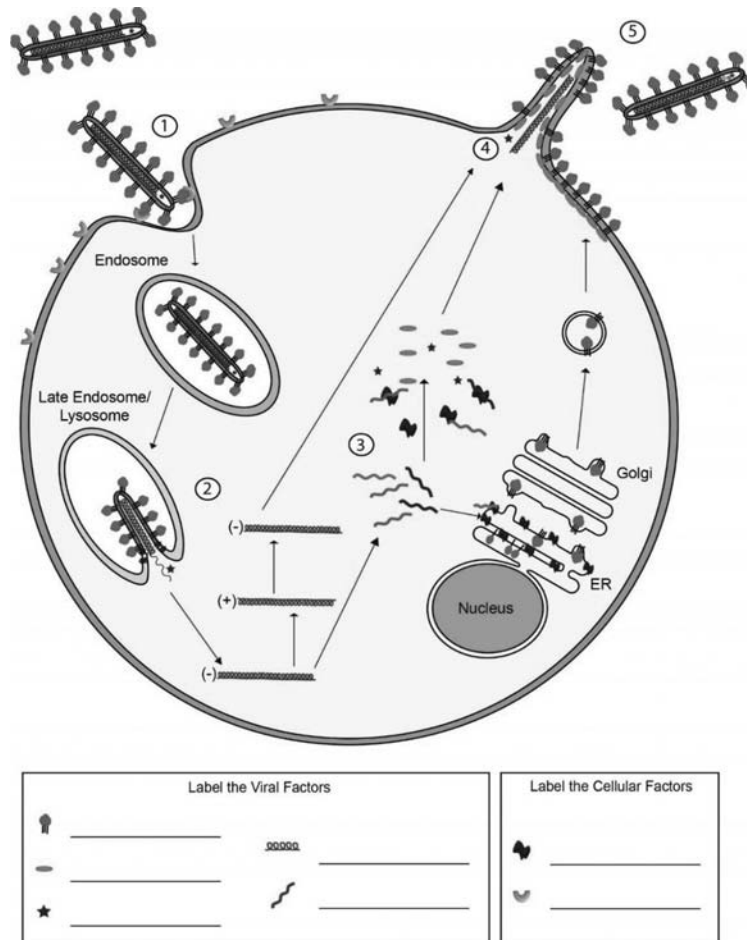
Please attempt to answer each question to the best of your ability. Where appropriate, please use bullet point instead of complete sentences. Partial credit will be given.

1. 2.5 pts. What type of organism/entity causes Ebola hemorrhagic fever? (*Remember*)
 - a. Bacteria
 - b. DNA Virus
 - c. RNA Virus
 - d. Protist
 - e. Archaea
2. 2.5 pts. True or False: Human disease-causing Ebola virus can be spread through the air. (*Remember*)
3. 2.5 pts. A virus is not made of cell(s) and is thus considered "acellular." Why, specifically, is the Ebola virus particle not considered a cell? (*Analyze*)
4. 2.5 pts. Ebola virus is categorized by the NIH as a Category A Priority Pathogen, meaning it is considered high risk to national security and public health. Provide two reasons you think it received this classification. (*Evaluate*)
5. 2.5 pts. Examine the diagram showing the life cycle of the Ebola virus (in Question 6). What are the five major steps used by Ebola virus (and common to all viruses) to infect cells? (*Remember*)
 - 1: _____
 - 2: _____
 - 3: _____

4: _____

5: _____

6. 2.5 pts. Label the key viral and cellular factors in the indicated areas of the diagram (adapted from White & Schornberg, 2012). (*Apply*)



7. 2.5 pts. Formulate a hypothesis as to why there is more than one mechanism of viral entry into host cells. Which mechanism does Ebola virus use? (*Create*)
8. 2.5 pts. What are the three main mechanisms for viral release from a host cell? Which mechanism does Ebola virus use? (*Remember*)
9. 2.5 pts. ZMapp consists of three antibodies against Ebola virus. Which of the following is true? Circle all that apply. (*Understand*)
- a. It is a vaccine.
 - b. It is a drug to be given post-exposure.
 - c. The antibodies each target different viral proteins.
 - d. The antibodies all target GP.
 - e. It is an antibiotic.
10. 5 pts. A new filamentous virus is identified deep in the forests of Africa and named Zambezi virus. In the extracellular viral particle, it has a protein (S) at the surface that is important for binding to the host cell, a protein (E) that is found under the lipid envelope and seems to be important during assembly and in maintaining the virus particle structure, and another protein (R) that helps replicate the negative-strand RNA and generate positive-strand mRNAs. Due to its similarities to Ebola and Marburg viruses, it is classified as a filovirus. For each of the proteins, identify the protein that serves a similar function for the Ebola virus. Options include: GP, (-)ssRNA, VP40, L, lipid. (*Analyze*)

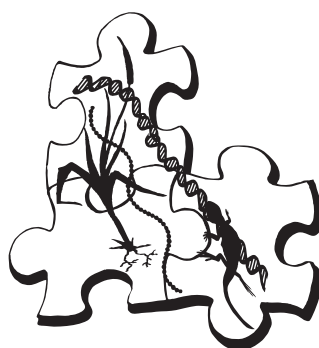
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Zambezi Virus Protein	Ebola Virus Protein
S	
E	
R	

Appendix III

The questions from the pre-/post-assessment mapped to misconceptions identified in *Development and Validation of Virus and Ebola Misconceptions Assessment (VirEMiA): Ebola Virus Misconceptions in College Students* (Miller, 2016) in both U.S. and international populations. NA = not addressed in the question set. (Question #) = questions that could potentially address the misconception depending on the student's answer.

Misconceptions	Questions from Pre-/Post-Assessment
The etiological agent of Ebola virus disease (EVD).	Question 1
The definition of a virus.	Question 3
The number of Ebola virus strains.	NA
The mode of transmission of Ebola virus.	Question 2
The incubation period of EVD.	(Question 4)
The treatment options and curability of EVD.	(Questions 4, 9)
The initial symptoms of EVD.	NA
The cause of death from EVD.	NA
The mortality/death rate of EVD.	(Question 4)



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