MedEdPORTAL® The AAMC Journal of Teaching and Learning Resources

Original Publication

Open Access

The Zombie Virus Pandemic: An Innovative Simulation Integrating Virology, Population Health, and Bioethics for Preclinical Medical Students

Jennifer M. Jackson, MD*, E Shen, PhD, Timothy R. Peters, MD

*Corresponding author: jstancil@wakehealth.edu

Abstract

Introduction: Understanding population health in the context of infectious disease outbreaks is an important physician competency. However, identifying effective ways to engage early medical students in this content remains a challenge. We designed an innovative pandemic simulation for first-year medical students utilizing the pop culture theme of zombies. **Methods:** This 2.5-hour simulation was conducted in 2018 and 2020 during students' virology course. Student teams collected and analyzed data to formulate hypotheses for the source pathogen. The teams completed reports explaining their diagnostic hypotheses, infection containment recommendations, and resource allocation recommendations. Learners completed an evaluation of the simulation through an online survey. Responses were analyzed using descriptive statistics; narrative responses were analyzed qualitatively for themes. A content analysis was performed on students' reports. **Results:** Two hundred eighty-four medical students participated in this activity. Nearly all respondents agreed that the small-group format (98%, 2018 and 2020) and pace and duration (92%, 2018; 94%, 2020) were appropriate and that the activity was intellectually stimulating (97%, 2018; 96%, 2020). Learner engagement measures were high (90%-97%, 2018; 83%-96%, 2020). Analysis of students' reports revealed evidence of cognitive integration of virology, population health, and bioethics concepts, including integration of new learning content. **Discussion:** Collaborative problem-solving during a simulated zombie-themed pandemic provided preclinical medical students with an engaging opportunity to integrate virology, population health, and bioethics concepts. Implementing this event required advanced planning, use of multiple spaces, learning materials preparation, and recruitment of several faculty, staff, and actors.

Keywords

Virology, Population Health, Epidemiology, Bioethics, Simulation, Biostatistics & Epidemiology, Clinical Reasoning/Diagnostic Reasoning, Ethics/Bioethics, Health Systems, Infectious Disease, Editor's Choice

Educational Objectives

By the end of this activity, learners will be able to:

1. Interpret epidemiological data to identify potential risk factors, likely location of origin, and mode(s) of transmission for an unknown pathogen in a simulated pandemic.
2. Collect information about patients' presenting symptoms, illness course, and potential exposures.
3. Generate a differential diagnosis by comparing the features of an unknown pathogen to known diseases.
4. Use their hypotheses to develop treatment recommendations for infected patients in a simulated pandemic.
5. Develop recommendations for public health prevention and containment measures for their local community in a simulated pandemic.
6. Create an ethically defensible strategy for allocating a limited resource in a simulated pandemic.

Citation:
Jackson JM, Shen E, Peters TR. The zombie virus pandemic: an innovative simulation integrating virology, population health, and bioethics for preclinical medical students. *MedEdPORTAL*. 2020;16:11016. https://doi.org/10.15766/mep_2374-8265.11016

Introduction

Understanding population health in the context of infectious disease outbreaks is an important physician competency. Since the Accreditation Council for Graduate Medical Education[1,2] and the Association of American Medical Colleges[3] issued calls for curricular reform to ensure inclusion of population health in graduate and undergraduate medical curricula, medical schools have increased the amount of curricular time devoted to population health,[4] although curricular integration of public health

systems content has been limited.[5] Implementing instruction on health systems has remained a challenge due to faculty perceptions that health systems science is too advanced for medical student trainees and to logistical concerns about limited space in an already crowded curriculum.[6]

To enhance our preclinical medical students' instruction on infectious disease outbreaks and to increase their engagement with population health, epidemiology, virology, and bioethics, we designed and implemented an innovative simulated viral pandemic activity using the pop culture theme of zombies, in which infected patients manifested with severe bleeding, aggressive behavior, and focal neurological findings. In addition to teaching about disaster preparedness,[7] educators have used the zombie pop culture theme to engage learners in other disciplines, including mathematics[8,9] and evidence-based medicine appraisal.[10] Guitton and Cristofari state that beyond enhancing learner engagement, use of the zombie theme as an educational strategy "could also break the boundaries between subjects, showing connections between them and encouraging students to tackle various problems in original ways."[11]

Several educators have previously published outbreak- or pandemic-related instructional activities for medical trainees.[12-24] Although most these activities, like ours, use an interactive, small-group format and some also involve self-directed learning, the learning content of focus among these resources differs from that of our simulation. For example, Lindemann, Owens, Qualm, Frentz, and Kevghas developed a tabletop exercise for third-year medical students on a simulated influenza pandemic, which focuses on concepts of incident command, disaster planning, health care system management, and communication between government and health care parties.[12] Similarly, the pandemic exercise for first-year medical students developed by Drowos, Lizotte-Waniewski, and Louda focuses on the roles of and interactions between various parties in the community public health system during large health care crises.[13] Tegzes, Mackintosh, Meyer, Redman-Bentley, and Aston developed a problem-based learning (PBL) activity based upon a historical tuberculosis outbreak; although this activity, like ours, includes instruction on public health systems and ethical issues related to infectious outbreaks, the goals of the activity focus on interprofessional collaboration.[15] Unlike our media-rich, immersive simulation that is highly interactive and creates an authentic learning environment, the aforementioned resources are tabletop, paper-based activities.

A few authors have published simulation-based activities related to infectious outbreaks, although, again, the learning content of focus varies from that of our simulation.[25-30] For example, Mahoney, Suyama, and Offen used an innovative, hands-on outbreak activity in which student teams are tasked with caring for simulated inpatients while being challenged by resource limitations in this clinical setting; although this simulation, like ours, touches on resource allocation issues, the activity focuses on communication and teamwork among health care team members.[25] O'Keeffe and colleagues created a 4-hour, simulation-based workshop on Ebola readiness for health care professionals; while this simulation, like ours, involves a hemorrhagic fever virus, their workshop targets a more advanced learner group and focuses on direct clinical care issues related to personal protective equipment (PPE).[26] None of the aforementioned learning activities includes learners' direct, active involvement in collecting clinical data about infected patients, and few require learners to interpret epidemiological data and/or perform diagnostic problem-solving.

The purpose of our zombie-themed pandemic simulation was to provide our preclinical students with a challenging and engaging learning activity requiring them to integrate virology, population health, and bioethics concepts, including both previously encountered and new learning content, in order to problem solve.

Methods

Educational Context

We implemented this learning activity for all first-year medical students during their virology course after they had completed the core virology didactic instruction, approximately 6 months into their first year of medical school. Prior to this course, students had completed the anatomy, biochemistry, genetics, and bacteriology courses. In their longitudinal clinical skills course, they had learned how to obtain a full medical history. In their longitudinal population health and epidemiology course, they had encountered content on modes of disease transmission, measures of morbidity and mortality, interpretation of risk ratios and confidence intervals, descriptive statistics, and disease outbreak concepts, including case definitions, incubation periods, epidemic curves, and source types (e.g., point source, common source, propagated person-to-person spread, etc.). In addition, these students were concurrently participating in a longitudinal bioethics course during which they encountered fundamental ethics principles (justice, beneficence, nonmaleficence, autonomy) and in a longitudinal PBL course during which they practiced differential diagnosis generation using a list of pathophysiological categories of disease. In this PBL course, these students regularly engaged in self-directed learning to address questions identified when reviewing cases.

We designed this simulation by collaborating with course directors of the bioethics and population health and epidemiology courses, with the goal of deliberately building in relevant tasks requiring learners to integrate learning content from all of these disciplines as they problem-solved during the simulation. We also identified new learning content from bioethics—resource allocation concepts—for which the pandemic simulation would serve as students' introductory exposure. Our overall objectives for incorporating these topics were to reinforce this learning content in an integrated, clinical context and to enhance learners' engagement with these disciplines. A simulation experience in which students practiced cognitive integration of learning content from multiple disciplines was supported by Kolb's experiential learning theory, according to which learning is grounded in experiences during which learners are actively engaged with their environment.[31] We designed this simulation as an instructional activity and not as an assessment.

Learner Prerequisites

Prior to participating in this activity, learners had to have had instruction on viral structure and function, viral pathogenesis, viral reassortment, vaccines, clinical features of viruses for multiple illness types (e.g., encephalitis viruses, respiratory viruses, systemic viral infections, etc.), as well as some instruction on antiviral medications and their mechanism of action. From an epidemiology standpoint, learners needed to know how to interpret risk ratios, confidence intervals, and epidemic curves and to have a basic understanding of disease transmission and infection prevention measures. From a clinical skills standpoint, learners needed to know how to collect a full history. As for bioethics, learners needed to have a basic understanding of the core ethics principles (listed above). Although resource allocation concepts were addressed in this activity, prior training on this topic was not essential for learners to complete their assigned tasks during the simulation.

Event Preparation

The following is a summary of the simulation preparation steps and space setup; additional details about these elements are included in the applicable appendices. To assist with planning, a comprehensive list of event preparation tasks is provided in Appendix A: Logistics.

Staff recruitment: Several months prior to the simulation event, we identified two administrative medical education staff to assist with simulation planning. We met with this core staff team regularly to review preparation tasks. A few days prior to the simulation, we met with a larger group of additional administrative staff recruited to help with this event (some of whom served in multiple roles over the course of the event). Additional details about staff roles and recruitment are provided in Appendix A: Logistics.

Logistics: We conducted this simulation event in multiple areas throughout our medical school building, including several portions of our simulation center, in order to accommodate the space needs of our learner group's size. We scheduled this attendance-mandatory event on students' academic calendar, assigned students to specific clinical analyst teams, and assigned a unique simulation rotation schedule to each team (see Appendix A: Logistics for additional details on space planning and the rotation schedule).

Actor recruitment and training: We recruited actors from the University of North Carolina School of the Arts and from our medical school's standardized patient pool to play the parts of the infected patients and informants, as well as various roles in each of the prefilmed videos used during the simulation event. Additional details about actor recruitment and preparation for each of these roles are included in Appendix A: Logistics, Appendix C: Actor Training and Event Day Prep, and Appendix D: Informant Scripts.

Learning materials preparation: Prior to the day of the event, we designed a simulated Emergency Operations Center (EOC) website to house several files created for the event, which we instructed students to review during the simulation. These files included simulated epidemiological data (Appendix F) and frontline clinician videos (Appendices G-K). The EOC website also included a downloadable copy of the template for students' team reports (Appendix L) and a mechanism for uploading a copy of their completed reports to the site (additional information about constructing this website is included in Appendix A: Logistics). We provided instructions for students on how to access this website, including how to submit their completed reports, in the mission packet document distributed to students at the beginning of the simulation (Appendix B).

We printed hard copies of the following documents in advance of the event:

- Mission packets (Appendix B): enough copies for all students to each have one of their own.
- Informant door briefs (Appendix E): enough copies for one copy to be placed at each door, corresponding to the applicable informant case.

Space preparation/staging: To enhance learner engagement during the simulation, we staged the learning spaces to create a more realistic ambiance within which students encountered the simulation's actors. The time required to set up the staging for this activity will vary depending on one's logistical plan and based upon the number of staff available to assist, but it can take from 30 minutes up to 2 hours. The staging for this simulation included the following:

- Staging of the infected patient rooms.
- Simulated biohazard zones throughout the simulation center.
- Simulated news media videos on screens throughout the simulation center.

Additional details about staging, including photographs of our implementation, can be found in Appendix M: Staging. An example of a simulated news video we developed and used as part of our staging is provided in Appendix N.

Event Implementation

This 2.5-hour simulation consisted of the following activities, a more detailed description of which is presented in the accompanying appendices. Educators can adjust the total duration of the simulation activity and the degree of the fidelity implemented (i.e., use of the media and staging described in this resource) according to their learner group size, space needs, and availability.

Large-group mission charge (learner orientation): To begin the simulation, we assembled all learners in a large-group classroom and played the 6-minute mission charge video, which served as students' introduction to the simulation and provided an overview of their tasks for the event: to investigate the source of a mystery pandemic, manifesting with zombie-like signs and symptoms (Appendix O: Mission Charge Video). Prior to this video, students had no knowledge of the nature of the learning activity other than the location to which they were to report at its start time and that their attendance was required.

Following the video, our staff distributed to all students a mission packet document, which included their team assignments, their team's assigned small-group meeting room, their team's assigned rotation schedule for the event, instructions for how to access data on the EOC website, and instructions for their assigned team report (Appendix B: Mission Packet). We then dismissed students from the large-group session to assemble with their teams in the assigned meeting rooms, review the instructions provided, and begin their assigned activities.

Pandemic investigation: For the remainder of the event, learners rotated among multiple activities according to their team's assigned schedules (see Appendices A: Logistics and Appendix B: Mission Packet); these activities included the following:

- Interviews of informants (30 minutes total duration; 15 minutes per informant interview): Students interviewed a series of actors portraying people who knew someone who had become infected with the pandemic virus; these informants provided information to students about patients' initial presenting symptoms and illness course leading up to their hospitalization. We assigned a total of four informants to each student team to interview during this portion of the activity.
- Patient viewing and interviews of frontline clinicians (10 minutes in duration): Through an adjoining window or computer-screen camera view, student teams viewed and interacted with a pair of clinicians working at the bedside of actors portraying infected patients. During this activity, students had the opportunity to ask clinicians questions to learn more about patients' hospital course, as well as physical exam and laboratory findings. For most of the encounter, the patients were sedated (acted asleep) but abruptly woke up near the end of the encounter, yelling and acting aggressively toward the bedside clinicians, for a brief jump scare to conclude this portion of the activity.
- Exploration of epidemiological data and frontline physician videos stored on the simulated EOC website: Students could use any remaining time outside of the above two scheduled activities to complete this (and the following problem-solving) task.
- Collaborative, small-group problem-solving related to their assigned tasks and composition of their team's report.

Updates from the field: At intervals throughout the simulation (at 1 hour, 1 hour and 30 minutes, and 1 hour and 50 minutes after the simulation start time), we emailed students updates from the field—additional simulated data to use in their investigation—which included the following (see Appendix P: EIS Updates):

- A simulated chart review from the regional tertiary care center, which provided a list of clinical features (presenting symptoms, physical exam findings, lab findings, and clinical outcomes) and the prevalence of each among infected patients.
- An electron micrograph image of the pandemic virus.
- An ethical dilemma and request for recommendations on how to allocate a limited resource found to improve patient survival.

As an alternative to emailing these documents to students, educators could upload them as additional data on the EOC website or distribute hard copies of them to student teams.

Student team reports: At the conclusion of the activity, we required each student team to submit a report that included (1) the team's hypothesis for the most likely pathogen causing the pandemic, (2) treatment recommendations based on that hypothesis, (3) infection prevention and containment recommendations for the local community, and (4) recommendations for approaching the resource allocation dilemma presented in the final update from the field (Appendix L: Team Report Template).

We required students to include explicit justification for each of these assigned tasks, citing data collected during the event—either from the EOC website or through self-directed learning online. For the resource allocation issue, we required students to justify their recommended approach using ethical principles.

Following completion of the 2.5-hour attendance-required activities (above), we permitted students up to an additional 1.5 hours to work on their team reports, if desired (up to the report submission deadline).

Concluding instructional session: Following the conclusion of the simulation, the virology course directors (Timothy R. Peters and Jennifer M. Jackson) conducted a structured, large-group, interactive session with students. During this 1-hour session, we reviewed relevant population health concepts of disease outbreak investigations; how to interpret the epidemiological data presented during the simulation; how to use epidemiological and clinical data to construct a differential diagnosis for the mystery virus; the molecular principles of viral genetic recombination, which underpinned the backstory of this case scenario; and relevant ethical issues occurring in large-scale disease outbreaks, including a list of approaches to the resource allocation issue. We encouraged students to reflect, interact, and ask questions throughout the session (Appendix Q: Concluding Instructional Session).

Program Evaluation

To assess students' evaluation of and engagement with the learning activity, we developed a learner evaluation survey. We sent the link to the survey to students following the simulation; students' completion of the survey was anonymous and voluntary. This survey asked students to assess the simulation's relevance to their future clinical role, evaluate elements of the event's instructional design and their effectiveness for helping students achieve the learning objectives, evaluate the event's effectiveness in stimulating students' interest in relevant disciplines and improving students' understanding of relevant clinical topics, and evaluate the quality of the videos and other materials used during the simulation. We also asked a series of questions assessing students' perception of engagement during the activity, using items adapted from a tool developed by Wiggins and colleagues.[32] The survey concluded with two open-ended, free-text items asking students to identify the most effective aspects of the activity and aspects needing improvement, respectively.

We analyzed learner responses to multiple-choice survey items using descriptive statistics. We qualitatively analyzed learners' narrative responses to open-ended questions to identify themes.

Learner assessment: As above, we required each student team to submit a single report on behalf of the team using a standardized team report template (Appendix L: Team Report Template). The virology course directors reviewed these reports following submission. Students' performance on these reports did not impact their virology course grade.

To evaluate students' engagement with the learning content and their performance of learning objectives 1-6, we qualitatively analyzed students' team reports by performing a content analysis.[33]

Results

Two hundred eighty-four first-year medical students participated in this simulated pandemic activity in January of 2018 ($n = 139$) and January of 2020 ($n = 145$). Sixty-six students completed the learner evaluation survey for the January 2018 implementation (47% response rate), and 47 students completed the postevent survey for the January 2020 implementation (32% response rate). Responses to multiple-choice items are presented in Tables 1, 2, and 3, and a summary of themes from the narrative comments is presented below.

Learners' evaluation of the instructional design of the simulated viral pandemic is presented in Table 1. Overall, students assessed the simulation as relevant for their future clinical role and felt that its instructional design was effective for meeting the learning objectives and for integrating learning material from multiple disciplines. Respondents indicated that the simulation improved their understanding of complex physiological and systems-based concepts presented in the simulation.

Learners' assessment of learning engagement–related measures during the simulated viral pandemic is presented in Table 2.

Table 1. Learners' Evaluation of the Instructional Design of the Simulated Viral Pandemic, January 2018 (n = 66; 47% Response Rate) and January 2020 (n = 47; 32% Response Rate)

Question	Extremely or Quite Relevant (%)	
	2018	2020
How relevant were the knowledge and skills used during this learning activity to your role as a future physician?	71	85
	Yes (%)	
	2018	2020
Was the small-group format of this learning activity appropriate for the learning content presented?	98	98
Were the pace and duration of this learning activity appropriate for the learning content presented?	92	94
	Extremely or Quite Effective (%)	
	2018	2020
How effective was this learning activity for practicing each of the following tasks?[a]		
Analyze clinical, epidemiological, and molecular data during an infectious outbreak to develop hypotheses for the most likely etiologic pathogen.		87
Recommend treatment(s) for patients suffering from an infection due to an unknown source, based on one's hypotheses about the underlying pathogen.		80
Recommend public health prevention and containment measures for one's local community during a large-scale infectious outbreak.		76
Identify the essential elements of disaster preparedness relevant to large-scale infectious outbreaks at the national level and in one's medical center and surrounding local community.		77
Apply ethical principles to develop ethically defensible strategies for allocation of limited resources during a large-scale public health crisis.		66
How effective were each of the following activities for learning about the clinical features of the disease presented in this simulated viral pandemic?		
The informant interviews.	90	80
The front-line clinician interviews/patient viewing rooms.	83	81
	Significantly or Moderately (%)	
	2018	2020
How much did this learning event improve your understanding of the following?		
Emerging viral infections.	93	87
The neuroanatomy and physiology of aggression.	61	62
The physiology of sepsis.	73	45
Pathophysiology of disseminated intravascular coagulation.[a]		64
How health care systems respond to large-scale health crises.	88	89
How to approach ethical issues related to large-scale health crises.	80	68
	Extremely or Quite Effective (%)	
	2018	2020
How effective was this learning activity for each of the following?		
Reinforcing knowledge learned during the virology course.[a]		83
Learning new information about infectious diseases not otherwise addressed in the virology course.[a]		74
Reinforcing history taking and communication skills you have learned in the clinical skills 1 course.	90	74
Reinforcing epidemiological data analysis and interpretation skills learned in the population health & epidemiology course.	79	68
How effective was the debrief session for addressing each of the following objectives?[a]		
Review how to interpret risk ratios to identify risk factors for a disease.		79
Determine a disease's likely mode of spread by interpreting its epidemic curve pattern (i.e., point source, continuous common source, or propagated person-to-person spread).		79
Use information about a virus's molecular structure to identify potential pathogens.		82
Identify distinctive clinical features that provide helpful clues to the underlying disease.		82
Understand the ethical principles used by clinicians and public health officials to manage large-scale infectious outbreaks.		79
Understand how new viruses can emerge as the result of viral recombination events.		87
	Weighted Average	
	2018	2020
What was the overall effectiveness of the simulated viral pandemic activity?[b]	8.9	8.7

[a]Item assessed on the 2020 learner evaluation survey only.
[b]Rated on a 10-point Likert scale (1 = *poor,* 10 = *excellent*).

Table 2. Learners' Assessment of Learning Engagement–Related Measures During the Simulated Viral Pandemic, January 2018 (n = 66; 47% Response Rate) and January 2020 (n = 47; 32% Response Rate)

Question	Extremely or Quite Enjoyable (%)	
	2018	2020
How enjoyable was the simulated viral pandemic activity?	90	83
	Yes (%)	
	2018	2020
Was the problem-solving aspect of this activity intellectually stimulating?	97	96
	Significantly or Moderately (%)	
	2018	2020
How much did this learning event stimulate your interest in the following?		
Virology	95	89
Epidemiology	83	77
Neurology	55	47
Hematology[a]		45
Critical care medicine	71	70
Medical ethics	54	40
Disaster response and preparedness[a]		83
	Strongly Agree or Agree (%)	
	2018	2020
How much do you agree or disagree with each of the following statements?		
Small-group discussion during this learning event contributed to my understanding of virology.	97	94
Explaining information to my small group during this learning event improved my understanding of it.	93	94
Having material explained to me by my small-group members improved my understanding of the material.	91	91
I was focused during this learning event.	90	87
I worked hard during this learning event.	93	83
I made valuable contributions to my group's work during this learning event.	95	89
Overall, the other members of my group made valuable contributions during this learning event.	93	94

[a]Item assessed on the 2020 learner evaluation survey only.

Overall, students' responses indicated high degrees of learner engagement with each of the constituent learning content areas as well as high degrees of learner engagement with peers during the activity.

Learners' evaluation of the learning materials developed for the simulated viral pandemic is presented in Table 3. Students evaluated all learning materials as being high quality and effective for enhancing the realism of the simulation.

Table 3. Learners' Evaluation of the Learning Materials Developed for the Simulated Viral Pandemic, January 2018 (n = 66; 47% Response Rate) and January 2020 (n = 47; 32% Response Rate)

Question	Extremely or Quite Effective (%)		Extremely or Quite Effective for Learning About the Disease's Clinical Features (%)		Rating of Quality: Excellent or Good (%)		Extremely or Quite Effective for Enhancing the Simulation's Realism (%)	
	2018	2020	2018	2020	2018	2020	2018	2020
How effective was the Emergency Operations Center website for presenting the learning materials for this event?[a]	86							
How effective was the epidemiological data on the Emergency Operations Center website for enhancing the realism of the simulation?[b]		91						
The mission charge video to students at the beginning of the event.					100	98	91	83
The video of the emergency medicine clinician's report.					98	96	91	87
The video of the intensive care clinician's report.			80	74	98	98	93	91
The video of the neurologist's report.			67	70	94	91	89	85
The video of the pathologist's report.			79	80	96	93	94	93
The video of the ethicist's remarks.					90	87	79	79
The videos of simulated news reports about the pandemic.					91	89	89	89

[a]Item assessed on the 2018 learner evaluation survey only.
[b]Item assessed on the 2020 learner evaluation survey only.

Below are themes noted in students' narrative responses to the learner evaluation survey following the simulated viral pandemic in January 2018 ($n = 66$; 47% response rate) and January 2020 ($n = 47$; 32% response rate).

- Learner engagement:
  - Students appreciated the time and effort faculty and staff invested in preparing for this event.
    - "Outside of any educational benefit, we felt incredibly well loved. The effort and time that so many faculty went through for our education and our enjoyment was astounding."
    - "AMAZING. I can't believe the effort that was put into it. Honestly, because so much effort was put into it, I was motivated to really get involved."
    - "I was incredibly impressed by the committed role that the instructors and the actors took on, not to mention the intensity of the online resources and depth to which they had been created (i.e. the videos made local to Winston Salem, etc.)."
  - Students found the simulation to be a fun and engaging learning experience.
    - "Truly this was an A+ and by far the coolest and most helpful integrative activity we've done in medical school."
    - "This was such a fun way to work with classmates and put our knowledge to real world use. It was probably one of the most fun days of medical school so far."
    - "Honestly, it was all effective. The organization was amazing and it made learning virology so much fun."
  - The immersive nature of the simulation enhanced students' engagement.
    - "The simulation felt real, and I felt like I was in a movie set."
    - "The virus and media efforts for the outbreak were fantastic and created a sense of urgency."
    - "These were all done so well and with such detail to really get you in the zone."
  - The challenging nature of the assignment was intellectually stimulating.
    - "The 'stretch' assignment (by combining two viruses) made it very intellectually stimulating!"
    - "The creative aspect of having no information building up to a disease was incredibly useful."
- Learning content:
  - Students gained unique insights about the public health system's role in disease outbreaks.
    - "This was awesome on multiple levels. For one thing, I think it provided a brief glimpse of what might happen in a real disease outbreak, and how it might overwhelm the resources of a health care system. It also provided another opportunity to think through a clinical public health problem methodically while, at the same time, being flexible enough to incorporate new information into the problem as it was provided. Great educational experience."
    - "While I don't think I would become a researcher at the CDC, it did help me get a glimpse into the complicated process that occurs during outbreaks like this. I know as a future physician, wherever I end up, I will have to be a part of the process somehow, and this was a cool sneak peek."
  - Students recognized and appreciated the integration of learning content from multiple disciplines.
    - "The way the event tied together Medicine and Patients in Society, Population Health/Epidemiology, and Virology was excellent."
    - "I thought the activity was very educationally relevant, as it required me to use interviewing/patient-centered skills as well as my knowledge of the science behind infectious disease."
  - The diagnostic investigation was helpful for reviewing viral diseases learned in class.
    - "Creating a differential diagnosis of possible pathogens was helpful in reviewing what their characteristics are."
    - "The discussion was a great way to go over concepts learned in class concerning different symptoms associated with viruses."
  - The ethical issue of resource allocation broadened students' perspective of outbreak management.
    - "Having to include the ethics of how to use our resources was eye-opening to me. The whole thing made me realize that during a pandemic, the patients are people—with families and friends—and balancing mitigating a huge public health risk with caring for an individual human being seems both daunting and incredibly important."
- Effective instructional design elements:
  - Students' active involvement in collecting data was effective for learning.
    - "I think the active portions were most effective—interviewing [informants] and the doctors."

        - "The interviews with family and friends of patients were engaging and informative. I appreciated how that part of the activity was extremely hands-on."
    - Students recognized the importance of learning how to identify relevant questions (hypothesis-driven data gathering).
        - "We were given the opportunity to ask patients/family members the questions we thought were important to figure out what was going on. There is no better way to teach this than to let us experience it."
        - "It felt reflective of real life because all the key factors weren't just presented to us, we had to dig and ask the right questions to get relevant information."
    - Students enjoyed working in teams to problem solve.
        - "I think the problem solving in groups was the most effective piece of this activity. In particular, having to use the information given to us (in intervals) to prove or disprove our own, or others', suggestions was useful in evaluating how much we knew or did not know."
    - The time constraints encouraged students to focus their interviews to identify the most relevant questions for the informants and clinicians.
        - "The consistent time reminders and tight schedule was great for contributing to our focus and keeping us on task."
        - "Because of the time restriction, we had to split up as a group and essentially present the information to each other, which was great."
        - "When we were under time constraints and interviewing the physicians working in the ICU—we had to think quickly about important questions."
- Aspects students found challenging:
    - Some student groups focused primarily on identifying the source virus at the expense of the ethics task.
        - "My group was simply too involved in solving the 'What virus is this?' problem in the time allotted that we didn't really get into the ethical considerations of disease outbreaks and resource allocation."
        - "Having a faculty facilitator for at least the first 15-20 minutes of the activity may have been helpful to aid us in 'not getting lost' in all the data or the 'drama' of the case. I think we more or less forgot to address the ethical aspects of this for that reason."
    - Many students did not consider the possibility of a novel virus, which made identifying a good match difficult.
        - "I think it would have been a little better to instruct students to think outside the box—we all thought that you were trying to have us understand a specific disease and didn't realize that your goal was to get us to combine diseases that we knew."
        - "It would have been helpful to know that there wasn't necessarily one CORRECT and absolute answer and that we should try to be creative as possible. If we had known that there was more creativity allowed, we may have thought about the lab techniques to develop a super virus. We were working really hard to narrow it down to one and not another."
    - Students identified diagnostic errors that impacted their clinical reasoning.
        - "Overall, I think we did well as a group. I think collectively we all still need to work on what we now know as 'anchoring' or locking into a particular diagnosis early on and then paying attention only to information that confirms it. Looking back on it in light of some information we learned just this week about medical errors, our group was guilty of that diagnostic sin. I'm sure most groups did this, but it was a good way to learn the valuable lesson of not settling on a diagnosis prematurely."
    - Engagement with the activity was more difficult if timed too close to the core virology instruction (2020 implementation).
        - "I think it would have been more effective to have more time in between the virology lectures and the simulations. It would have been more useful if I had more time to learn the material."
        - "Doing this event after a weekend between learning virology and the event would make the reinforcement stronger."

The qualitative analysis of learners' narrative comments indicated students found the simulation to be a highly engaging experience and especially appreciated its immersiveness. Students identified the most effective aspects of the activity to be working in teams to problem solve, the challenging nature of the assignment, and the active roles students had in data collection during the simulation. Many students invested a lot of effort into trying to identify a single, known viral pathogen as the source of the pandemic, and some were frustrated to discover (later, in the concluding instructional session) that the pathogen was a novel virus composed of genetic material from multiple sources, not having considered this possibility in their groups. Students in the 2020 implementation noted that the close proximity (timing) of the event relative to prior core instruction limited their degree of engagement and expressed a desire for

more time to digest the relevant virology material prior to the simulation.

The content analysis of the diagnostic reasoning–related elements (learning objectives 1-4) of students' team reports from 2018 ($n = 20$ reports) revealed evidence of cognitive integration of learning content from infectious diseases, population health, clinical skills, and bioethics, including both new and previously encountered learning content. Students tended to use a compare-contrast analytical approach to diagnostic reasoning, with a smaller subset also employing a causal approach.[33]

In the content analysis of the 2018 student reports for infection prevention and containment measures (learning objective 5), we identified nine unique codes for public health systems and disaster response-related tasks. Students' most common recommendations were in the infection containment domain, focusing primarily on health care facility measures to mitigate transmission, with fewer reports addressing the community public health and individual citizen levels. As for their approach to resource allocation (learning objective 6), students' reports cited 11 distinct ethical approaches. The most commonly cited were prioritizing those most likely to benefit (16 reports, 80%) and prioritizing health care personnel to ensure an ongoing workforce during the pandemic (10 reports, 50%).

Discussion

In this zombie-themed pandemic simulation, we provided our preclinical students with an engaging learning experience during which they worked collaboratively in teams to collect and interpret clinical and epidemiological data and integrated virology, population health, and bioethics concepts to address a series of problem-solving tasks. Learners' evaluation of this simulation indicated a high degree of learner engagement, which was enhanced by the many staging elements used, students' active roles in collecting data from multiple sources, and the challenging nature of the assigned tasks. Through the mission charge and frontline physician videos, patient viewing, clinician and informant interviews, and EOC website, our simulation created a multimedia, authentic learning environment that learners reported was engaging and facilitated knowledge transfer. Students explicitly recognized and appreciated that the activity provided an opportunity for them to integrate knowledge and skills from multiple disciplines in order to problem solve. Despite the fact that the simulated pandemic was based upon a fictional virus, most students recognized the relevance of the simulation's learning content and activities to their future clinical roles. To our knowledge, ours is the first zombie-themed pandemic exercise designed to enhance instruction on population health, epidemiology, virology, and bioethics for preclinical medical student learners.

During this simulation, learners engaged in the active experimentation and concrete experience stages of Kolb's experiential learning cycle by applying virology, population health, epidemiology, and bioethics knowledge from the classroom to a simulated pandemic through data collection and interpretation, as evidenced by their team reports. In the concluding instructional session following the simulated pandemic activity, students engaged in the reflective observation and concept formation stages of Kolb's cycle by reflecting on their performance and formulating diagnostic problem-solving strategies.[31]

Because this simulation activity has the potential to serve as a learning tool for so many aspects of medicine—epidemiological data interpretation, public health systems' response to large-scale health crises, disaster response and preparedness, interprofessional collaboration, viral genetics and recombination, diagnostic reasoning, and a host of bioethics issues—educators have a variety of options when selecting the learning objectives for the event. However, one of the challenges of an integrative learning activity like this is determining which aspects of the learning content to focus on during the concluding instructional session (and to what degree). Because each topic in this list was too complex to address in its entirety, we chose to focus our concluding instructional session on those topics we felt our particular learner group (first-year medical students) would find most relevant at their stage in training—epidemiological data interpretation for infectious outbreaks, diagnostic reasoning, and viral recombination mechanisms—with relatively less time spent discussing the ethical issues and disaster response elements. Other educators may choose to focus instead on other aspects of these topics, depending upon the issues most intriguing and relevant to their specific learner groups.

Because ethical principles are so crucial to appropriate implementation of pandemic management, we made a point of including a specific task where learners addressed a resource allocation issue in their reports. We were disappointed to observe in students' reports and among learners' feedback that some groups focused primarily on identifying the source virus at the expense of the ethics task. To mitigate this, we recommend that educators explicitly emphasize to learners the expectation of ensuring the ethics task is appropriately addressed on their teams' reports.

Students in both implementation groups explicitly struggled with diagnostic uncertainty while attempting to identify the source pathogen in this simulated pandemic. Some students reported they spent a lot of time trying to identify a single microorganism that explained all of the clinical features present in these patients and, in the process, explored information about a host of different viruses, both within and beyond their core curriculum. Although some learners appreciated that this process served as a good review of the viral diseases presented in the virology course, others expressed frustration that they spent so much time looking for a single virus when the underlying pathogen ultimately was a novel virus arising from multiple source viruses. Some of these students were frustrated that they were not explicitly told by instructors that the disease in this simulation was not a real one, whereas we assumed that it would be readily apparent to students that the disease was fictional simply based on the fact that zombies are a fictional construct. We acknowledge students' underlying assumptions and recognize that we could have been more explicit about this issue when initially presenting the assignment to students. However, because the challenging nature of this stretch assignment added so much to their engagement during the simulation, we chose to limit our guidance and instead allow students to independently determine how to approach this diagnostic puzzle. Some student groups did consider the possibility of a novel virus consisting of phenotypical features of multiple viruses as the result of a recombination event, indicating they were able to successfully identify a plausible explanation for the clinical scenario.

Perhaps the most gratifying and unexpected outcome of planning this simulation was the high degree of faculty and staff engagement in the planning process, as well as the excitement and anticipation that progressively developed among this group as we neared the simulation day. While the initial implementation was being planned, more and more staff and faculty volunteered to be involved as they identified the event as a unique and engaging opportunity to be involved in instructional delivery. Each year since the initial implementation, recruitment of faculty and staff for this event has continued to be very successful. Some of the most engaging experiences for us, our faculty, and our staff were creating the original news report videos and frontline clinician report videos, many of which starred our medical education and instructional design staff. Therefore, we recommend that educators strongly consider creating some of their own videos for this event—with visuals of their own school, medical center, and geographic locale—and involve interested faculty and staff whenever possible. Doing so not only builds engagement among the planning team members but also personalizes the event for learners who view these videos during the simulation.

Lessons Learned

In our initial implementation in 2018, we did not allocate time between the mission charge video and students' first scheduled activity (the informant and patient viewing/clinician interviews). Learner feedback that year indicated students really needed some time at that point to familiarize themselves with the event's materials and schedule and to meet with their teams briefly to create a plan for the day. Therefore, we changed the logistics from our original format to allocate 20 minutes of student preparation time in the small groups before the other scheduled activities began. Students also indicated in their feedback that they needed more explicit orientation to the simulation, including what materials were available on the EOC website (materials some students admitted they did not realize were there) and clarity on how to spend their time during the informant and clinician interview activities. So, in subsequent implementations of the simulation, we made the learner orientation instructions more explicit (provided in both the mission charge video and the mission packets). Both of these modifications significantly improved students' ability to navigate their list of activities.

Students struggled more with neurology than other learning content during this simulation, most likely because they had not yet encountered neurology in the curriculum at that point (the neurology course followed microbiology in our first-year students' curriculum). We knew, when first designing the event, that that this would be the case, so we worked closely with the neurology instructors to ensure that the information presented would be understandable without prior exposure to that content. Several students did comment that they appreciated the neurology content of this simulation in retrospect, after completing the neurology course.

Although we required attendance for nearly all portions of the simulation, we chose to make the concluding instructional session attendance optional, as it was video recorded with the option of asynchronous learner review. Though this resulted in a relatively small number of learners at this session (approximately 30-40 in 2018 and approximately 20-25 in 2020), the smaller learner audience did facilitate more instructor-learner interaction throughout the session's discussion. Regarding our initial concluding instructional session, students' feedback indicated we needed to enhance instruction on novel virus emergence and viral recombination mechanisms, so we revised this session to better explain these concepts.

In our 2018 implementation, we scheduled this event near the end of the virology course on a Monday afternoon, with a weekend between the core virology didactic content and the simulation. By contrast, for the 2020 implementation, the virology course dates were such that the core virology instruction was completed on a Thursday, and this simulation event was then scheduled for the following Friday morning. Several students' narrative comments on the 2020 learner evaluation indicated that this timing made it much more challenging for them to problem solve and engage with the learning content, as they had not had much time to digest the core virology content. We recommend that educators take this into consideration when selecting the timing for their own implementation of the simulation.

An important issue to note is the inconsistent use of PPE elements donned by actors in the videos produced for this simulation, which presents a safety hazard to health care workers. To address this, we recommend educators clarify for learners the importance of consistent PPE use during any relevant patient encounter, which PPE would be considered appropriately protective in a case such as this, and that inconsistent PPE use can lead to potential exposures among health care personnel.

A thoughtful, balanced portrayal of patients of all community populations is an important goal for any medical curriculum. Therefore, our institution has actively recruited minority community members to serve as actors for instructional events, including this one. Some of the videos in this simulation portray patients of color who are ill and violent and who are restrained by health care providers who are White. These videos were selected due to the outstanding performances of these actors. However, such images may be perceived as reinforcing negative stereotypes, although this is completely unintentional. We encourage educators who are contemplating the implementation of this simulation to consider this issue, as we have in response to student comments, and to take special care to balance these portrayals and discussion. Educators can consider discussion of important social justice topics in the context of this simulation.

Because emotionally powerful simulation exercises can, at times, evoke unexpected or dysphoric responses in learners (e.g., reminders of loved ones lost to the recent coronavirus pandemic), it may be helpful to have counseling services aware of such instructional events and prepared to provide support as needed.

Limitations

As this was a single-institution study, the generalizability of our findings may be limited to the specific case scenario and the curricular context of this activity within our curriculum. Educators at other institutions may have limited access to the resources required to implement this activity (e.g., access to standardized patients, access to instructional designers to assist with creation of an EOC website) and therefore may not be able to implement all aspects of the simulation in the same way we did. In addition, response rates to our postevent learner evaluation surveys were limited. Because students' reports represented the work of student teams, performance on these reports did not reflect each individual student's approach to the assigned tasks; a different evaluation approach would be needed to assess individual learners' performance. Although this activity introduces learners to several aspects of public health, health systems, disaster response and preparedness, and bioethics, it does not provide comprehensive training in these areas and therefore needs to be supplemented with additional instruction and practice opportunities in order for learners to achieve competency in these domains.

Future Directions

Future directions of this work include adapting the activity for other learner groups, including more advanced medical learners and other health professions students, as well as development of learning activities providing opportunities for interprofessional collaboration, given the inherent interprofessional nature of public health and large-scale infectious outbreak management. In addition, robust assessment methods, including additional content analysis of student reports, are needed to measure students' learning outcomes and knowledge transfer as well as their engagement in the relevant learning content. Other medical educators can help build a library of highly interactive and media-rich simulation-based activities for medical trainees that can be shared among programs.

Appendices

A. Logistics.docx
B. Mission Packet.docx
C. Actor Training and Event Day Prep.docx
D. Informant Scripts.docx
E. Informant Door Briefs.docx
F. Epidemiological Data.docx
G. Emergency Medicine Physician Video.mp4
H. Critical Care Physician Video.mp4
I. Neurologist Video.mp4
J. Pathologist Video.mp4

K. Ethics Video.mp4

L. Team Report Template.docx

M. Staging.docx

N. News Video Example.mp4

O. Mission Charge Video.mp4

P. EIS Updates.docx

Q. Concluding Instructional Session.pptx

All appendices are peer reviewed as integral parts of the Original Publication.

Jennifer M. Jackson, MD: Associate Professor, Department of Pediatrics, Wake Forest School of Medicine; Co-Course Director, Clinical Skills Curriculum, Wake Forest School of Medicine; Co-Course Director, Virology Course, Wake Forest School of Medicine; Assistant Dean for Curricular Innovation, Wake Forest School of Medicine

E Shen, PhD: Assistant Professor, Department of General Internal Medicine, Wake Forest School of Medicine; Director of Healthcare Teaching and Learning, Wake Forest School of Medicine

Timothy R. Peters, MD: Professor, Department of Pediatrics, Wake Forest School of Medicine; Associate Dean for Educational Strategy & Innovation, Wake Forest School of Medicine; Co-Course Director, Virology Course, Wake Forest School of Medicine

Acknowledgments

We gratefully acknowledge the contributions of many individuals among our faculty, Academic Affairs staff, standardized patients, and students whose efforts were central to making this work successful. We extend our sincerest gratitude to Sharon Korczyk and Kendall Freeman for their tireless efforts in planning, leading, and executing the operations for this event each year; to Erin Haynes, SP Program Manager, for her assistance in recruiting and managing the standardized patients; to Andrea Nance and Aarti Ramanathan for instructional design assistance; to our Virology Student Design Team for their valuable insights in planning the event; to Dr. David Miller, Dr. Christine Bishop, and Gerardo Maradiaga for their collaboration in designing the learning content; to Scott Zigler, Gregory Walter, Dale Girard, and student actors from the University of North Carolina's School of the Arts for their collaboration; to Dr. David Manthey, Christopher Craig, DMSc, MMS, PA-C, Ken Bishop, David Holder, and Brad Woodward for their expertise in disaster preparedness; and to Dr. Matthew Miles, Dr. Nancy Rosenthal, Dr. Patrick Reynolds, Dr. Christine Bishop, Dr. Stephen Powell, Dr. Christopher Davis, and Dr. Katherine Poehling for their assistance in developing and producing the frontline clinician videos.

This event would not have been possible without the support and enthusiasm of Dr. Mary Claire O'Brien, Professor of Emergency Medicine, who fostered our vision for this event and provided the spark for our simulation's first and most memorable implementation.

Disclosures

None to report.

Funding/Support

None to report.

Prior Presentations

Jackson JM, Eder MD, Maurier DT, Clemens EA, Galloway JL, Peters TR. The zombie pandemic: an innovative simulation exercise to support integration of basic and clinical sciences for preclinical medical students. Presented at: Generalists in Medical Education Annual Meeting; November 1, 2018; Austin, TX.

Jackson JM, Peters TR. Connecting the dots: evidence of successful cognitive integration among preclinical medical students during a simulated viral pandemic. Presented at: International Association of Medical Science Educators Annual Meeting; June 9, 2019; Roanoke, VA.

Ethical Approval

The Wake Forest School of Medicine Institutional Review Board approved this study.

References

1. Dyne PL, Strauss RW, Rinnert S. Systems-based practice: the sixth core competency. *Acad Emerg Med*. 2002;9(11):1270-1277. https://doi.org/10.1197/aemj.9.11.1270
2. *ACGME Common Program Requirements (Residency)*. Accreditation Council for Graduate Medical Education; 2018. Accessed March 13, 2020. https://www.acgme.org/Portals/0/PFAssets/ProgramRequirements/CPRResidency2019.pdf
3. *Report II—Contemporary Issues in Medicine: Medical Informatics and Population Health*. Association of American Medical Colleges; 1998. Accessed January 19, 2020. https://www.aamc.org/system/files/c/2/497660-contemporaryissuesinmedmedicalinformaticsreportii.pdf
4. Sabharwal R. Trends in medical school graduates' perceptions of instruction in population-based medicine. *Analysis in Brief*. 2002;2(1). Accessed January 19, 2020. https://www.aamc.org/system/files/reports/1/aibvol2no1.pdf
5. Patel MS, Lypson ML, Davis MM. Medical student perceptions of education in health care systems. *Acad Med*. 2009;84(9):1301-1306. https://doi.org/10.1097/ACM.0b013e3181b17e3e
6. Gonzalo JD, Caverzagie KJ, Hawkins RE, Lawson L, Wolpaw DR, Chang A. Concerns and responses for integrating health systems science into medical education. *Acad Med*. 2018;93(6):843-849. https://doi.org/10.1097/ACM.0000000000001960
7. Kruvand M, Bryant FB. Zombie apocalypse: can the undead teach the living how to survive an emergency? *Public Health Rep*. 2015;130(6):655-663. https://doi.org/10.1177/003335491513000615
8. Lofgren ET. Unlocking the black box: teaching mathematical modeling with popular culture. *FEMS Microbiol Lett*. 2016;363(20):fnw225. https://doi.org/10.1093/femsle/fnw225

9. Lofgren ET, Collins KM, Smith TC, Cartwright RA. Equations of the end: teaching mathematical modeling using the zombie apocalypse. *J Microbiol Biol Educ*. 2016;17(1):137-142. https://doi.org/10.1128/jmbe.v17i1.1066

10. Blevins AE, Kiscaden E, Bengtson J. Courting apocalypse: creating a zombie-themed evidence-based medicine game. *Med Ref Serv Q*. 2017;36(4):313-322. https://doi.org/10.1080/02763869.2017.1369239

11. Guitton MJ, Cristofari C. Does surviving the zombie apocalypse represent a good model of human behavior in response to pandemics? *J Public Health Manag Pract*. 2014;20(4):375-377. https://doi.org/10.1097/PHH.0000000000000043

12. Lindemann J, Owens M, Qualm C, Frentz S, Kevghas C. Pandemic scenario tabletop exercise. *MedEdPORTAL*. 2007;3:692. https://doi.org/10.15766/mep_2374-8265.692

13. Drowos J, Lizotte-Waniewski M, Louda D. Pandemic influenza: what if? *MedEdPORTAL*. 2015;11:10162. https://doi.org/10.15766/mep_2374-8265.10162

14. Vukotich C, Stebbins S. Surviving a hepatitis A outbreak: don't lose the lessons learned. *MedEdPORTAL*. 2011;7:9003. https://doi.org/10.15766/mep_2374-8265.9003

15. Tegzes J, Mackintosh S, Meyer T, Redman-Bentley D, Aston S. To be or not to be: an interprofessional problem-based learning case introducing the One Health Initiative. *MedEdPORTAL*. 2013;9:9623. https://doi.org/10.15766/mep_2374-8265.9623

16. May L, Omron R, Piller M, Haile-Mariam T, Scott J. Integrating emerging infections education into medical education: an innovative approach. *Med Educ Online*. 2007;12(1):4461. https://doi.org/10.3402/meo.v12i.4461

17. May L. Teaching outbreak preparedness in the emergency medicine clerkship: an innovative approach. *MedEdPORTAL*. 2007;3:586. https://doi.org/10.15766/mep_2374-8265.586

18. Cassoobhoy M, Wetterhall SF, Collins DF, et al. Development of an interactive bioterrorism and emerging infections curriculum for medical students and internal medicine residents. *Public Health Rep*. 2005;120(1)(suppl):59-63. https://doi.org/10.1177/00333549051200S112

19. Mahoney J. Public health emergency tabletop exercise. *MedEdPORTAL*. 2006;2:395. https://doi.org/10.15766/mep_2374-8265.395

20. Langmuir AD. The use of the "blind" problem in teaching epidemiology. *Int J Epidemiol*. 1975;4(4):253-256. https://doi.org/10.1093/ije/4.4.253

21. Carney JK, Schilling LM, Frank SH, et al. Planning and incorporating public health preparedness into the medical curriculum. *Am J Prev Med*. 2011;41(4)(suppl 3):S193-S199. https://doi.org/10.1016/j.amepre.2011.05.026

22. Morrow CB, Novick LF. A case exercise in public health preparedness: a community outbreak of influenza-like illness. *J Public Health Manag Pract*. 2005;11(4):306-310. https://doi.org/10.1097/00124784-200507000-00008

23. Marshall CS, Yamada S, Inada MK. Using problem-based learning for pandemic preparedness. *Kaohsiung J Med Sci*. 2008; 24(3)(suppl):S39-S45. https://doi.org/10.1016/S1607-551X(08)70093-7

24. Rega PP, Fink BN. Immersive simulation education: a novel approach to pandemic preparedness and response. *Public Health Nurs*. 2014;31(2):167-174. https://doi.org/10.1111/phn.12064

25. Mahoney J, Suyama J, Offen B. Pandemic influenza preparedness: a patient care and team training simulation. *MedEdPORTAL*. 2009;5:7887. https://doi.org/10.15766/mep_2374-8265.7887

26. O'Keeffe DA, Bradley D, Evans L, et al. Ebola emergency preparedness: simulation training for frontline health care professionals. *MedEdPORTAL*. 2016;12:10433. https://doi.org/10.15766/mep_2374-8265.10433

27. Atlas RM, Clover RD, Carrico R, Wesley G, Thompson M, McKinney WP. Recognizing biothreat diseases: realistic training using standardized patients and patient simulators. *J Public Health Manag Pract*. 2005;11(6)(suppl):S143-S146. https://doi.org/10.1097/00124784-200511001-00026

28. Bellan SE, Pulliam JRC, Scott JC, Dushoff J, et al; Organizing Committee MMED. How to make epidemiological training infectious. *PLoS Biol*. 2012;10(4):e1001295. https://doi.org/10.1371/journal.pbio.1001295

29. Fass MF. Teaching emerging diseases: a strategy for succeeding with nonmajors. *Microbiol Educ*. 2000;1(1):20-25. https://doi.org/10.1128/154288100X14285805520001

30. Spinello EF, Fischbach R. Problem-based learning in public health instruction: a pilot study of an online simulation as a problem-based learning approach. *Educ Health (Abingdon)*. 2004;17(3):365-373.

31. Kolb DA. *Experiential Learning: Experience as the Source of Learning and Development*. Prentice-Hall; 1984.

32. Wiggins BL, Eddy SL, Wener-Fligner L, et al. ASPECT: a survey to assess student perspective of engagement in an active-learning classroom. *CBE Life Sci Educ*. 2017;16(2):ar32. https://doi.org/10.1187/cbe.16-08-0244

33. Jackson JM, Skelton JA, Peters TR. Medical students' clinical reasoning during a simulated viral pandemic: evidence of cognitive integration and insights on novices' approach to diagnostic reasoning. *Med Sci Educ*. 2020;30(2):767-774. https://doi.org/10.1007/s40670-020-00946-9

Received: March 19, 2020
Accepted: June 27, 2020
Published: November 12, 2020