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Development and Validation of Virus and Ebola Misconceptions Assessment (Viremia): Ebola Virus Misconceptions in College Students

Michele Miller
Wright State University

DEVELOPMENT AND VALIDATION OF *VIRUS AND EBOLA MISCONCEPTIONS ASSESSMENT* (VirEMiA): EBOLA VIRUS MISCONCEPTIONS IN COLLEGE STUDENTS

A thesis submitted in partial fulfillment of the
Requirements for the degree of
Master of Science

By

MICHELE ELAINE MILLER
B.S., University of Indianapolis, 2014

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY **Michele Elaine Miller** ENTITLED **Development and Validation of *Virus and Ebola Misconceptions Assessment* (VirEMiA): Ebola Virus Misconceptions in College Students** BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF Master of Science.

_____

William Romine, Ph.D.
Associate Professor of Biological Sciences
Thesis Director

_____

Barbara E. Hull, Ph.D.
Professor of Biological Sciences
Director of Microbiology and Immunology MS Program

Committee on Final Exam:

_____

William Romine, Ph.D.
Associate Professor of Biological Sciences

_____

Barbara E. Hull, Ph.D.
Professor of Biological Sciences

_____

Nancy Bigley, Ph.D.
Professor of Microbiology and Immunology

_____

Robert E. W. Fyffe, Ph.D
Vice President for Research and Dean of the Graduate School

ABSTRACT

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In this study an assessment (VirEMiA) on college students' knowledge and misconceptions of the Ebola virus was created and validated. VirEMiA was then used to determine what misconceptions college students have about Ebola, if there is a difference in misconceptions between students with and without a strong science background, and if Just-in-Time Teaching (JiTT) increases students' knowledge of Ebola and decreases their misconceptions.

VirEMiA was shown to be a valid and reliable assessment whether confidence was integrated (seprel=0.97) or not (seprel=0.98), and for measuring misconceptions (seprel=0.97). If psychology and nursing majors were considered to have a strong background in science, the difference in misconceptions between students with and without a strong background in biology was not statistically or practically significant ($t_{df=392}$=1.86, p=0.06, d=0.19). However, if psychology and nursing majors were not considered to have a strong science background, there was a statistically and practically significant difference in misconceptions between students with and without a strong science background ($t_{df=392}$=4.18, p<<0.001, d=0.64). When VirEMiA was used as pre-homework for a class utilizing JiTT, student got about 4.4 more questions on the post-test correct compared to the pre-test, and the difference in their scores is statistically and practically significant ($t_{df=116}$=9.11; p<<0.001; d=0.84). Students also had about 7 fewer

misconceptions after learning about Ebola, and this difference was practically and statistically significant ($t_{df=116}$=-9.80; p<<0.01; d=-0.91).

These results show VirEMiA to be a valid and reliable instrument for measuring students' knowledge and misconceptions. It also showed that students' with a strong background in science do have fewer misconceptions than students without a strong background in science, as expected.

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I. SCIENTIFIC INTRODUCTION

History

Ebola virus first emerged in Sudan between June and November 1976 with a 53% mortality rate, killing 150 out of 284 victims (Pourrut *et al.*, 2005). This strain became known as *E. Sudan* after the country in which it was discovered (Pourrut *et al.*, 2005). At almost the same time, another outbreak occurred in the Democratic Republic of Congo (DRC) between August and November 1976 with an 89% mortality rate killing 284 out of 318 victims (Johnson, 1978). This outbreak was where Ebola got its name because the outbreak occurred near the Ebola River (Johnson, 1978). This strain of Ebola became known as *E. Zaire* because the DRC was known as Zaire from 1965 to 1997, which was when this outbreak occurred (Pourrut *et al.*, 2005). In 1977, a nine-year-old girl in the DRC passed away due to hemorrhagic fever from the Zaire strain of Ebola (Heymann *et al.*,, 1980). Another outbreak occurred in 1979 between July and October in Sudan with a mortality rate of 65%, killing 22 out of 34 victims (Pourrut *et al.*, 2005). This was the second outbreak caused by the Sudan strain of Ebola (Pourrut *et al.*, 2005).

A new strain was identified in Reston, Virginia in cynomolgus monkeys imported from the Philippines in 1989 (Guenno & Galabru, 1997). Three more outbreaks from this strain occurred in Alice, Texas, Philadelphia, Pennsylvania, and Sienna, Italy. All monkeys infected with this strain came from the same exporter. Even though animal handlers at these facilities tested positive for Ebola, no human clinical cases were

associated because none of the workers developed clinical symptoms (Guenno & Galabru, 1997).

Ebola re-emerged for another three years in Africa 1994 (Pourrut *et al.,* 2005). The first person to get sick during this second period was a Swiss ethnologist in the Tai National Park in Ivory Coast who had just performed an autopsy on a chimpanzee (Pourrut *et al.,* 2005). The first outbreak from this period was due to the Zaire strain, occurred between January and July 1995 in the DRC, and had a mortality rate of 81% (killing 256/315 victims) (Khan *et al.,* 1999). The next outbreak occurred in two waves in Gabon between December 1994 and February 1995 (Georges *et al.,* 1999). The first wave struck gold-miners, some of whom went to the nearest hospital while sick, causing the second wave. The mortality rate of both these waves was estimated at 59% with 29 recorded deaths and 49 clinical cases, but was imprecise since the cases were diagnosed retrospectively and not all clinical cases were recorded (Georges *et al.,* 1999). In February 1996, another outbreak occurred in two villages killing 21 out of 31 affected (mortality rate of 67.7%) (Pourrut *et al.,* 2005). The third outbreak officially began when the first patients tested positive on October 1996 (Georges *et al.,* 1999). However, epidemiologists found it actually began two months before that. This outbreak lasted until March 1997 with 60 cases and 45 deaths (Georges *et al.,* 1999).

The next grouping of outbreaks occurred from 2000-2004 (Pourrut *et al.,* 2005). The first outbreak was actually a grouping of outbreaks with the first occurring in October 2001. Over these four years, 14 small outbreaks occurred in Gabon and the DRC from the Zaire and Sudan strain (Pourrut *et al.,* 2005).

However, the CDC states that the likelihood of the average US citizen getting infected with Ebola is almost zero (CDC, 2014).

Genome

When genes two through six of the Ebola virus were sequenced, it was discovered that Ebola's genome is organized similarly to paramyxoviruses and rhabdoviruses (Sanchez *et al.,* 1993). Seven polypeptides are translated from monocistronic mRNA including nucleoprotein, viral polymerase L, VP35, VP30, VP40, VP24, and a transmembrane glycoprotein (Saijo *et al.,* 2006). The order of genes are 3'-NP-VP35-VP40-GP-VP30-VP24-L-5' according to predicted amino acid sequence comparisons and in vitro translation (Sanchez *et al.,* 1993). The nucleoprotein encapsulates the RNA genome (Mühlberger *et al.,* 1999). The nucleoprotein associates with RNA-dependent RNA polymerase, VP30 and VP35 (Mühlberger *et al.,* 1999). VP35 is also an interferon antagonist, VP40 also facilitates particle formation and functions as the matrix protein, and VP24 interferes with interferon signaling (Basler *et al.,* 2000; Noda *et al.,* 2002; Reid *et al.,* 2006). The glycoprotein gene is only expressed through translational frameshifting or transcriptional editing and is encoded in two open reading frames which results in two proteins, each of which serves a different function (Guenno & Galabru, 1997). The primary product, secreted glycoprotein (SGp), is smaller, produced in large amounts, and nonstructural, while the other product is surface glycoprotein (GP) which helps enable the virus to enter into the cell cytoplasm and bind the virions to receptors on the cell. GP and SGp have the same 300 residue N terminal. SGp might interact with the immune system at the cellular or humoral level. This would result in cellular deletion or high-

affinity antibodies directed at the surface glycoproteins respectively (Guenno & Galabru, 1997).

Life Cycle

Ebola is zoonotic with its perseverance in a reservoir species found in endemic locations (Morvan *et al.,* 1999). Humans, apes, and possibly other mammalian species, like duikers, that are vulnerable to Ebola and able to infect humans are labelled as end hosts instead of reservoir species (Morvan *et al.,* 1999; Sabourin, 2015). There have been numerous efforts in the past to discover the reservoirs of each outbreak, but so far neither potential host nor vector have been identified in the wild (Morvan *et al.,* 1999). The three suspected reservoirs for Ebola are Franquet's epauletted fruit bat (*Epomops franqueti*), the little collared fruit bat (*Myonycteris torquata*), and the hammer-headed fruit bat (*Hypsignathus monstrosus*) (Leroy *et al.,* 2005). A hypothesis for why there have not been more Ebola outbreaks is that Ebola may be subclinical or asymptomatic in reservoir species until a stimulus, such as stress, change in food sources, co-infection, or pregnancy, activates Ebola (Feldmann & Geisbert, 2011).

Ebola enters the host through breaks or abrasions in the skin, mucosal surfaces, or by parental introduction (Guenno & Galabru, 1997). Viral RNA has been found in semen, genital secretions, skin, nasal secretions, and body fluids (Feldmann & Geisbert, 2011). Ingestion of contaminated foods is also a possible route of exposure (Feldmann & Geisbert, 2011). Incubation varies from 2-21 days, however, the average incubation time is 7-10 days (Guenno & Galabru, 1997). Ebola has a broad cell tropism including fibroblasts, macrophages, hepatocytes, monocytes, adrenal cortical cells, dendritic cells, endothelial cells, and numerous kinds of epithelial cells (Feldmann & Geisbert, 2011).

Macrophages, dendritic cells, and monocytes seem to be where the virus prefers to replicate and also seem to be important in viral dissemination (Feldmann & Geisbert, 2011).

Ebola's replication cycle is eleven steps (White & Schornberg, 2012). The virus gains entry through glycoprotein-dependent viral attachment to the host cell followed by a micropinocytosis-like process (White & Schornberg, 2012). Studies have shown L-SIGN and DC-SIGN act as cofactors for Ebola virus cell entry (Alvarez *et al.,* 2002). Before there is fusion of viral and endosomal membranes after cathepsin digestion of the glycoproteins, the glycoproteins must be proteolytically primed and triggered to induce the fusion (White & Schornberg, 2012). Niemann-Pick C1 (NPC1) is an entry factor necessary for Ebola Virus entry. NPC1 is a multimembrane-spanning protein that is mainly found in lysosomes and late endosomes and is ubiquitously expressed. The nucleocapsid is then released into the cytoplasm where genome replication, transcription, and translation occurs. Heterotrimers of modified glycoproteins are formed and delivered to the plasma membrane. Viral RNA and proteins are assembled, packaged into viral particles, fused with the host membrane and released through budding. Finally, glycoproteins are secreted. Researchers are focusing on learning more about how Ebola enters a cell and what receptors it uses because preventing the virus from entering the cell is an ideal anti-viral intervention (White & Schornberg, 2012).

Symptoms and Diagnosis

Initial symptoms include fever, malaise, myalgia, and sometimes chills (Saijo *et al.,* 2006). This is followed by gastro-intestinal and flu-like symptoms, conjunctival hemorrhage, melena, maculo-papulary rash, shock, epistaxis, hematemesis, petichae, and

encephalopathy (Ansari, 2014). Some additional symptoms of Ebola are prostration, conjunctival injection, anorexia, postural hypotension, nausea, oedema, vomiting, headache, abdominal pain, confusion, diarrhea, coma, chest pain, shortness of breath, cough, and nasal discharge (Feldmann & Geisbert, 2011; Saijo *et al.,* 2006). These symptoms indicate Ebola affects multiple systems including systemic, gastrointestinal, vascular, respiratory, and neurological (Feldmann & Geisbert, 2011). Hemorrhagic manifestations start at the peak of illness and include ecchymoses, petichiae, mucosal hemorrhages, post-mortem evidence of visceral hemorrhagic effusions, and uncontrolled oozing from venipuncture sites (Feldmann & Geisbert, 2011; Saijo *et al.*, 2006). Hemorrhages are only present in less than half of Ebola patients (Fauci, 2014).

Blood tests show leukopenia, thrombocytopenia, and amplified amounts of thrombin, aminotransferase, and partial thromboplastin (Fauci, 2014). During the acute phase, clinical laboratory diagnosis of viremia is only possible in developed countries since it is a BSL-4 agent (Ansari, 2014). Africa does not have any BSL-4 facilities, has a weak health system, and lacks the necessary resources which is why an epidemic is much more likely there (Ansari, 2006). Assays for the acute phase include using Vero or Vero E6 cell lines for viral isolation, antigen capture ELISA RT-PCR and real time quantitative PCR assays with appropriate controls, and IgM ELISA (Saijo *et al.,* 2006). Later in the disease more tests can be used including IgM and IgG ELISA using viral antigens (Saijo *et al.,* 2006). Autopsy tissues can also be used for antigen detection using in-situ hybridization techniques for detection of viral RNA, immunohistochemical aided detection of Ebola antigen, and immunostaining techniques (Ansari, 2014). Someone cannot tell if a suspected patient has Ebola just by looking at them, however.

From day 3 to 7-16 days after symptoms start, viral antigen can be detected in the blood (Feldmann & Geisbert, 2011). As long as the virus is in a patient's blood, they are contagious. IgM antibodies can appear in an infected person as early as day 2 after symptom onset and last until day 30-168 post infection. IgG antibodies appear around day 6-18 after symptom onset and remain for many years after. In fatal cases, patients exhibit clinical signs early on and typically die due to hypovolemic shock and multiorgan failure between day 6 and 16. In non-fatal cases, patients have a fever for several days before they start getting better around day 6-11. This is also about the time the humoral antibody response is found. Specific IgG and IgM responses seem to be connected with a momentary strong and early inflammatory response consisting of tumor necrosis factor α, interleukin β, and interleukin 6. However, this response has yet to be proven as the mechanism that prevents the fatal disease (Feldmann & Geisbert, 2011).

Pathogenesis and Immune Evasion

Detailed pathogenesis is not well understood (Feldmann & Geisbert, 2011). Researchers do know that the virus disseminates in the spleen, liver, and lymph nodes. There is significant lymphoid cell apoptosis and inflammatory response. The lymphoid cell apoptosis leads to lymphopenia and appears be an indicator of poor prognosis (Feldmann & Geisbert, 2011). Inhibition of type I interferon response is a big part of the pathogenesis of Ebola because it disables the innate immune response and the acquired humoral responses that causes uncontrolled viral dissemination and replication (Wong, Kobinger & Qiu, 2014). Dissemination leads to dysregulation of the coagulation cascade and macrophages producing pro-inflammatory cytokines, which causes shock and multi-organ failure (Feldmann & Geisbert, 2011).

The viral envelope (ENV) is involved in receptor binding and fusion of the virus to the cell membrane of the host (Ansari, 2014). The Ebolavirus ENV is highly glycosylated (Ansari, 2014). The glycans lead to ineffective antibody production because the glycans are highly variable and disposable (Wong, Kobinger & Qiu, 2014). This phenomenon is known as epitope shielding (Wong, Kobinger & Qiu, 2014). The area that the glycans are localized to is known as the mucin-like region (MLR) (Yang *et al.,* 2000).

Ebola infection triggers many inflammatory mediators such as interleukins 2, 6, 8, 10, reactive oxygen and nitrogen species, interferons, TNF α, monocyte chemoattractant protein 1, regulated upon activation normal T cell expressed and secreted (RANTES), and interferon-inducible protein 10 (Feldmann & Geisbert, 2011). Increased levels of reactive nitrogen species in the blood has been linked to mortality because it causes tissue damage, apoptosis of lymphocytes, hypotension, and loss of vascular integrity (Feldmann & Geisbert, 2011).

The Ebolavirus antagonizes the interferon alpha and beta host response (Ansari, 2014). VP24 dulls the cells response to IFN-α, -β, and –γ by preventing the hetero-dimerization of TYK-2 and homo-dimerization of JAK-1, which prevents the nuclear localization of the transcription factors consequently inhibiting the transcription of interferon stimulating genes (ISG's). VP35 has multiple inhibitory effects including inhibiting IRF-3 phosphorylation, IRF-7 inactivation, inhibition of Dicer dependent protein kinase R and IFN inducible ds-RNA activation (Basler *et al.*, 2000; Ansari, 2014). VP35 also binds ds-RNA and affects its recognition by RIG-1, impedes the upregulation of several co-stimulatory molecules and maturation of dendritic cells (Ansari, 2014).

Ebolaviruses neutralize the type 1 IFN system and causes the production of large quantities of moderately pro-inflammatory cytokines at the same time (Ansari, 2014). This contributes to uncontrolled viral replication and immune dysfunction (Wong, Kobinger & Qiu, 2014). Monocyte and macrophage infection causes amplified production of TNF-α, which contributes to lymphoid cell apoptosis, induces fever, and inhibits interferon α and β (Ansari, 2014).

Vaccine and Therapeutic Clinical Studies

In order to prevent the spread of Ebola, patients must be isolated and health care staff must use strict barrier nursing procedures (WHO, 2010). At this point in time, treatment strategies are symptomatic and supportive because no cure or vaccine that is FDA approved currently exists (Feldmann & Geisbert, 2011). Pre-diagnosis treatments include isolation, broad spectrum antibiotics, malaria treatment, and antipyretics. Analgesics and fluid substitutions should be given as needed. In developed countries, cerebral oedema, shock, secondary bacterial infection, coagulation disorders, and renal failure must also be managed (Feldmann & Geisbert, 2011).

There are several vaccines in Phase I clinical trials including Ad26-EBOV, MVA-EBOV, and recombinant protein Ebola vaccine Novavax (Sabourin, 2015). ChAd3-ZEBOV and rVSV-ZEBOV are currently in phase III clinical trials. ChAd3-ZEBOVis being developed by GlaxoSmithKline with the National Institute of Infectious Disease. The vector is a chimp-derived adenovirus 3 with Zaire Ebola Virus glycoproteins. After a single dose, 16 out of 16 chimps survived lethal challenge. rVSV-ZEBOV is being developed by BioProtection Systems and Merck Vaccines USA and in collaboration with Public Health Agency of Canada. It is an attenuated VSV with the native glycoproteins

exchanged with Zaire Ebola Virus glycoproteins. It is also a single dose vaccine where 20 out of 20 chimps survived lethal challenge (Sabourin, 2015).

There are also several therapeutics in different phases of clinical trials (Sabourin, 2015). These therapeutics include Favipiravir, Brincidofovir, ZMapp, TKM-100802, BCX-4430, Interferons, Amiodarone, Atorvostatin + Irbesartan +/- Clomiphene, FX06, and Zmab. Favipiravir is currently used to treat influenza and is in phase II. Brincidofovir is an antiviral that is used to treat cytomegalovirus and is also in phase II. ZMapp has three monoclonal antibodies against Ebola virus in animal models. TKM-100802 uses siRNA and BCX-4430 is a broad-spectrum direct-acting nucleoside analogue. Amiodarone has been reported to reduce case fatality ratio when compared to local norms but no statistical significance is known yet. FX06 is a peptide used in treating vascular leakage, but has only been used in two patients so far (Sabourin, 2015).

A study released in August, 2015 found that a recombinant, replication-competent vesicular stomatitis virus-based vaccine expressing a Zaire Ebolavirus glycoprotein (rVSV-ZEBOV) is a promising Ebola vaccine candidate (Henao-Restrepo *et al.,* 2015). After a patient was confirmed to have Ebola, all contacts and contacts of contacts were given the vaccine immediately or 21 days later (delayed) at a 1:1 ratio. 4123 people received the vaccine immediately while 3528 people received the delayed vaccine. There were no cases of Ebola virus disease in the immediate group, while there was 16 cases of EVD in the delayed group. The vaccine had an efficacy of 100% between both groups. It also had an effectiveness of 75.1% including all adults eligible for vaccination and an effectiveness of 76.3% including people not eligible for vaccination. 43 adverse events were reported with only one being causally related to vaccination thus far. These results

indicate rVSV-ZEBOV is highly efficacious and safe and will most likely be effective in preventing the spread of Ebola via a ring vaccination strategy (Henao-Restrepo *et al.,* 2015).

Four possible target populations have been identified for vaccination if another outbreak occurs (Ansari, 2014). 1) Populations where Ebolavirus has caused outbreaks, 2) populations where an outbreak is occurring, 3) health care providers and military population and 4) the intermediate hosts of Ebolavirus. However, there are several problems with these plans including how large the geographical areas of past outbreaks was, the logistics in getting the vaccine to such large populations, maintenance of a cold chain, ability of the vaccine to induce rapid immunity, ability of the vaccine to provide long lasting immunity, targeting wild animals, and that the vaccine doesn't adversely affect other wildlife populations (Ansari, 2014).

Ebola as a Biological Weapon

Ebola has the potential to be used as a biological weapon in a terrorist attack. In fact, two groups looked into using Ebola as a weapon in the past. In 1993, doctors and nurses from the cult Aum Shinrikyo travelled to Africa in a failed attempt to learn about and bring back samples of Ebola virus (Olson, 1999). The Soviet Union also attempted to turn Ebola into a biological warfare agent during the Cold War, but also failed (Maron, 2014). Since groups have attempted to use Ebola as a weapon, it has a high mortality rate, is easily disseminated, might cause social disruption, and could have an economic impact, it has been labelled a Tier 1/ Category A agent. This means research involving Ebola is very strict and limited (Bhattacharjee, 2011; Koenig, 2012).

There are three ways Ebola could be used as a biological weapon (Maron, 2014). The first would be to insert it into a bomblet that would spray the virus about 30 feet and infect people through cuts or by them touching their eyes or faces. The second is to infect people with Ebola and send them out in public when they are bleeding or projectile vomiting. The final way would be to modify it in some way like making it able to spread through the air (Maron, 2014). However, before a group can use Ebola, they first need to get it (Hummel, 2014). They would first have to find someone infected with Ebola. Then they would have to extract the virus from the infected person's blood, which requires specific equipment, a BSL-4 lab, and someone who knows what they are doing so they do not end up infecting everyone (Hummel, 2014). The U.S. Army Medical Research Institute of Infectious Diseases (USAMRIID) was able to transmit Ebola in an aerosolized form, but accomplished this by forcing monkeys to inhale large quantities of Ebola droplets through a breathing apparatus, which is extremely unrealistic (Hummel, 2014). Many agree that an attack with Ebola is unlikely since it is not easy to obtain, not easy to deploy, they would have to figure out how to aerosolize it, and it does not always cause mass casualties (Stewart, 2014; Hummel, 2014; Maron, 2014). Other reasons Ebola is not a good choice for a biological weapon is that the incubation period ranges from 2-21 days, and it would be easier to contain since it takes so long to spread (Stewart, 2014).

II. PAPER INTRODUCTION AND PURPOSE

Ebola

Ebola virus disease is caused by the Ebola virus. Ebolavirus belongs to the Filoviridae family which consists of non-segmented negative-strand RNA viruses (Guenno & Galabru, 1997). This family has two genera, Marburgvirus and Ebolavirus (WHO, 2014). Filoviruses are enveloped, filamentous, about 19.1 kb in size, and appear as bacilliform particles (Guenno & Galabru, 1997). There are five strains of Ebolavirus including Zaire (ZEBOV), Sudan (SUDV), Reston (RESTV), Taï Forest (or Côte d'Ivoire), and Bundibugyo (BDBV) which all differ in antigenicity, genomic composition, case-fatality rate, and pathogenicity (WHO, 2014). Reston Ebolavirus is the only nonpathogenic strain in humans (Fauci, 2014). The strain with the highest case-fatality rate is Zaire with a rate of 60-90% (Fauci, 2014). When describing Zaire Ebola, Richard Preston (1995) warned that Zaire could easily be a global problem due to how infectious it is and that there is no cure (p. 64-65). The case-fatality rate in Sudan Ebola virus is 40-60%, Bundibugyo strain is about 25%, and the only person infected with Taï Forest Ebola virus survived (Feldmann & Geisbert, 2011).

Ebola has a high case-fatality rate but with 12,182 confirmed deaths total between 1976 and 2014, it does not kill nearly as many people as influenza does with 36,000 deaths per year in the US alone, or HIV/AIDS with 1.5 million deaths in 2013, or malaria with an estimated 627,000 deaths worldwide (CDC Cases of Ebola Virus Disease in Africa, 2015; Romine, Barrow & Folk, 2013; WHO, 2012; WHO, 2013). The mortality

rate of the 2014/2015 Ebola outbreak was 51% (WHO, 2014). There are several other viruses and bacteria with higher mortality rates than Ebola's 2014/2015 outbreak including H5N1 with a mortality rate of about 60% and inhalation anthrax with a mortality rate of 80% or more (FDA, 2015; WHO, 2011). MERS/SARS has a lower mortality rate then Ebola's 2014/2015 mortality rate, however, with a mortality rate of 10% and 40% respectively (Kaye & Pollack, 2014).

People who are at risk of contracting Ebola include people who have had direct contact through splashes of bodily fluid to their nose, eye, mouth, a break in the skin, or a needlestick with blood or bodily fluids from someone with symptoms. Therefore the people most likely to be infected are people who live with or care for someone showing symptoms, or people who had direct contact with the body of an individual who passed away due to Ebola without proper PPE (CDC Ebola Guidance, 2015). There are several ways to prevent the spread of Ebola including wearing surgical masks, avoiding contact with infected dead bodies, avoiding bodily fluids of an infected person, quarantining people who are suspected of being infected, avoiding contact with host animals, and washing hands (Feldmann & Geisbert, 2011; Guenno & Galabru, 1997; CDC, 2015).

Ebola Misconceptions

After the recent Ebola outbreak, a multitude of misconceptions about Ebola Virus Disease (EVD) have been spreading across the globe. Three studies have been done to discover what these misconceptions are in Nigeria, Sierra Leone, and Yaounde. Those countries were chosen because there has already been an Ebola outbreak in them.

One study used a semi-structured questionnaire of 15 closed ended questions that were given by an interviewer in an attempt to learn more about the awareness, knowledge

and misconceptions about EVD in Nigeria (Shittu *et al.*, 2015). Chi-square analysis was used on the data to determine if respondents had poor, fair, or good knowledge of the causes, symptoms, and transmission of EVD. Respondents knowledge level was determined by the number of questions answered correctly. Respondents who correctly answered less than five questions were considered to have poor knowledge, five to nine correct were considered to have fair knowledge, and ten or more correct were considered to have good knowledge. Thirty-nine percent of participants had poor knowledge of EVD, twenty-five and a half percent had fair knowledge of EVD, and thirty-five and a half percent had good knowledge. Almost all of the participants had heard of Ebola and were aware that there was an epidemic in West Africa. Many of the participants had misconceptions about the transmission of Ebola, with 39.5% believing EVD is airborne, 8% thought they could get it from mosquito bites, and 6.5% from bacteria. Many also had misconceptions about treatments with 22% thinking EVD is curable, 19.8% believing EVD can be treated through traditional healers, 19% thinking EVD can be treated with spiritual healers, and 13.2% believing a salt and hot water bath could treat it. Another problem researchers found was that many of the participants knew how to prevent EVD, but admitted they would not take the appropriate measures. For example, 57.2% felt that reducing contact with infected people would prevent spread of EVD, but only 34% said that they would (Shittu *et al*, 2015). A similar study (CRS, 2014) was also completed in Sierra Leone.

Another study used a multi-stage cluster sampling design (CRS, 2014). In this study, all of the participants had heard of Ebola and the majority knew it was in Sierra Leone. Participants in this study had many of the same misconceptions about

transmission and treatment as participants in the previously mentioned study including the belief that Ebola was transmitted by air or mosquito bites (33.3%), it can be treated with a spiritual healer (20%), and that a salt and hot water bath can treat it (40%). This paper showed many people do not understand the way Ebola is transmitted with many participants not correctly identifying all the ways it can be spread including through an infected persons other bodily fluids (41%), breast milk (13%), semen (17%), blood (32%), shaking hands or physical contact with an infected person (55%), and by eating fruit eaten by bats (33%). The participants were split over their perceived risk of contracting Ebola (34%) or not (36%). This study also found means of prevention had a great number of misconceptions with only 39% of participants being able to identify three means of protection. The last area of misconceptions this paper found is what Ebola is with only 41% knowing Ebola is a virus. Two percent of the remaining participants believed it was caused by God, evildoing, witchcraft, or a curse (CRS, 2014).

Another report used a six-item multiple choice questionnaire that focused on five variables of interest including 1) knowledge of risk factors, 2) knowledge of symptoms, 3) care, 4) prevention, and 5) misconceptions about the disease (CMSC, 2015). In this study 5.2% of participants stated they knew nothing about Ebola and the overall level of misconceptions about Ebola in the population was 10.8%. Most people knew that Ebola is a highly infectious disease originating in bats and animals (78.3%), the virus is transmitted by an infected person (80.3%), and only health authorities should help a suspected case (78.26%). Fewer people knew that fever is the first symptom of Ebola (63.6%), and that bleeding, body weakness, and vomiting are common symptoms that follow (49.3%). Some knew not to come into contact with an infected person (65.7%).

These researchers found several important specific misconceptions in the study. Misconceptions about Ebola virus are that it has been invented, created by whites, and is caused by articles brought from Europe. Misconceptions about how someone gets infected with Ebola are by not washing hands, not believing in Jesus, and not being hygienic. Further, people were found to believe erroneously that bleeding, headache, vomiting, and diarrhea were the initial symptoms of Ebola. Misconceptions about other signs of Ebola include chronic diarrhea, weight loss, and HIV and Tuberculosis. Misconceptions about what to do when someone shows signs of Ebola infection are to pray, abandon the person, and to not worry about a dead person. Finally, participants in this study expressed that Ebola infection can be prevented by eating bitter kola, by the same person who created the virus, vaccination, by drinking clean water, and by drinking onion and Nescafé without sugar (CMSC, 2015).

Just in Time Teaching

Just-in-Time Teaching (JiTT) is a way for professors to determine what misconceptions students have and use these misconceptions as a framework for teaching. This makes JiTT a promising method for helping educate students about a topic like Ebola that is rife with misconceptions. JiTT starts with a pre-instruction assignment that is meant to pique the students interest on the topic they are about to learn in class (Novak, 2011). The responses are due a few hours before class, allowing the professor time to incorporate insights gained from the homework into the upcoming lesson. This allows the professor to tailor the class to the cognitive level of the students, making the class as relevant as possible for those specific students at that specific time. When using JiTT, professors still need to have pre-planned activities, but also need time allotted for

responding to the responses on the homework. In order for JiTT to be successful, two things must occur. The first is that the assignment must be carefully constructed and based on validated educational research. The second thing is that the student responses must be integral to the lesson and not just mentioned (Novak, 2011). Numerous studies have shown that if JiTT is successfully implemented, students will have moderate to significant cognitive gains (Hake, 1998; Crouch & Mazur, 2001; Formica, Easley, & Spraker, 2010; Arons, 1979; Hestenes & Halloun, 1995). Hake found that while traditional courses have pre- post-test gains in the teens, JiTT courses have gains of 40-70% (1998).

Need of the Study

Previous work related to assessment of students' knowledge of viruses has focused on factual knowledge of viruses such as the size of viruses (Jones & Rua, 2006), virus structure and function, the effects of viruses on the body, the nature of the immune system (Simonneaux, 2000), and the mechanism by which vaccinations protect the body (Byrne & Grace, 2010). Little research has been done about the misconceptions people have about viruses. Hasan, Bagayoko, and Kelley define a misconception as an understanding of something that is different than the accepted understanding and that interferes with gaining more knowledge on the subject (1999, p 294). The three studies that have been done were in Africa and showed that some of these misconceptions can lead to disease spread. No studies have been published on misconceptions about Ebola in developed countries or focusing on college students.

Even though research on misconceptions in Africa has already been done (Shittu *et al*, 2015; CRS, 2014; CMSC, 2015), there is still a need for research to be done in the

USA. College students were selected as the target population of this research for a variety of reasons. The first reason is that it is the age people start paying attention to the news (Vincent & Basil, 1997). Another reason is that they will soon be helping run this country. Finally, I plan on teaching at the college level so understanding how students develop misconceptions will help me be a better educator. Ebola was chosen as the subject because it was all over the news in 2014 due to the epidemic and there is a fear of it being used as a biological weapon. Also, misconceptions about Ebola can lead to panic and disease spread. Some misconceptions that can lead to disease spread are that people are no longer infectious after they die, people are no longer infectious when they stop having symptoms, and some remedies like a salt water bath can cure people infected with Ebola. This test has also been written so some questions can apply to any virus simply by changing Ebola to the other virus and changing an answer to the correct answer for the virus if none of the answer choices apply to that specific virus.

Purpose of the Study

The purpose of this study is to ascertain some misconceptions college students have about Ebolavirus through the creation and validation of a multiple choice questionnaire. Misconceptions between science majors and other majors will be compared to see if there is a difference in misconceptions between students with a strong science background and those without. By using this study to learn more about the misconceptions, WHO, CDC, and healthcare workers will know what misconceptions the public has that needs to be addressed to mitigate another Ebola epidemic or pandemic in the future and hopefully help prevent people getting infected with Ebola or unnecessary panic due to a misconception.

Research Questions

The following questions will be addressed in this study:

1. To what extent is this questionnaire a valid and reliable measure for college students' misconceptions about Ebola?
2. What are some misconceptions college students have about Ebolavirus?
3. Is there a difference in misconceptions between science majors and other majors?
4. Does just in time teaching increase students' knowledge about Ebola?

Limitations of the Study

The following are the anticipated limitations of the study:

1. The study will only involve college students at Wright State University.
2. Response selection by non-science majors may be influenced by misunderstanding of scientific terms. The Certainty of Response Index (CRI) will be used to discover possible problem questions to be fixed before the next round of data collection.
3. A student selecting an incorrect answer does not necessarily mean they have a misconception over the content of the question. It could be lack of knowledge. The CRI will be used in conjunction with Virus and Ebola Misconception Assessment (VirEMiA) to determine if an incorrect response is in fact a misconception or if it is lack of knowledge.

III. METHODS

Methods for Misconception Analysis

This chapter includes four major sections with several parts in each section (Figure 1) as detailed below. The first section describes how the literature review was conducted and used to create Personal Knowledge Statements (PKSs), and how the PKSs were revised throughout the study. The second section explains how the pilot VirEMiA was created, experts' analysis of the assessment, and how it was revised based on the experts suggestions. The third section discusses how the first round of data collection was conducted, analysis of the validity of the assessment, how VirEMiA was revised based on the validity analysis, and experts' review of the assessment. The fourth section details the second round of data collection, analysis of reliability, analysis of Ebola misconceptions college students have, and if there was a difference in misconceptions between science majors and other majors. Another study was also performed to see if Just-in-Time Teaching helps address misconceptions and knowledge about Ebola.

Stage 1: Literature Review, Creation of Personal Knowledge Statements (PKSs)

Literature Review

The content of VirEMiA was established through a literature review. Information from the literature review determined possible misconceptions as well as the correct information about Ebola virus. Papers for the review were found through "Google

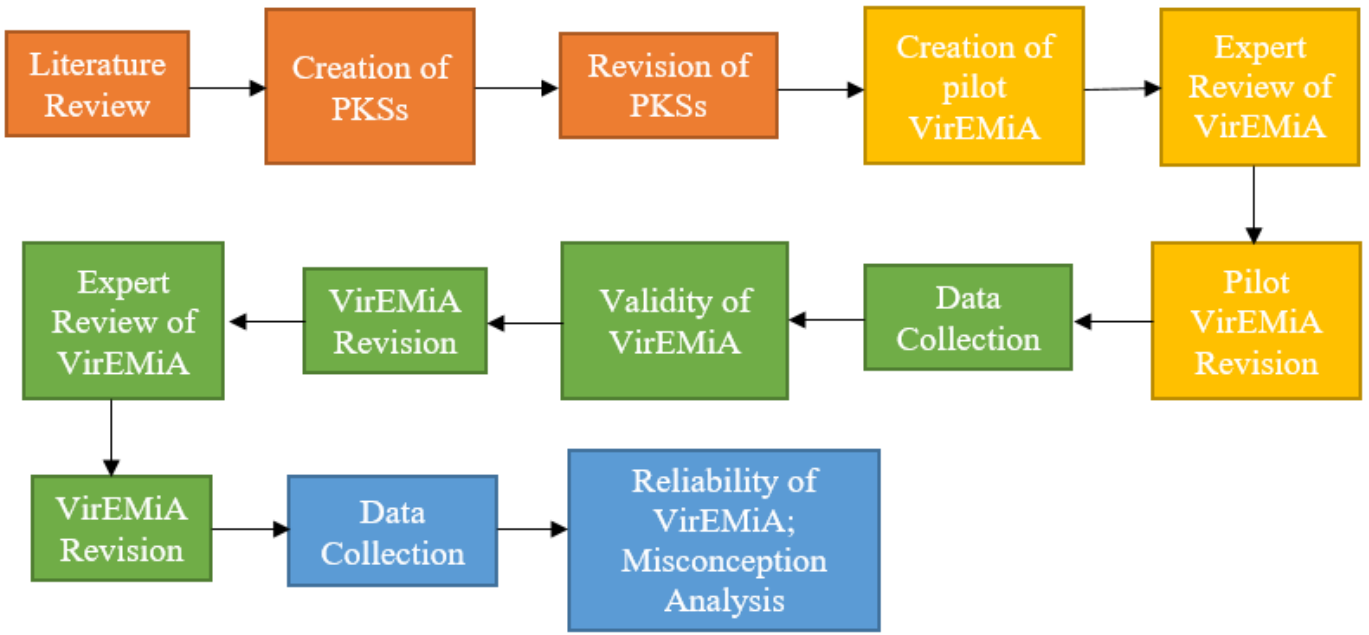

Figure 1. Methods Flowchart for the Development and Analysis of VirEMiA Orange=Stage 1; Yellow=Stage 2; Green=Stage 3; Blue=Stage 4

Scholar" using key terms such as "Ebola", "Misconceptions", and "Ebola Virus Disease". Other papers were found through contacting experts in the field.

Personal Knowledge Statements

Before an assessment could be created, a researcher must identify personal knowledge statements (PKSs). These PKSs state the information the researcher had determined an individual needs to know to have complete understanding about a topic. Based on the results of the literature review, the following content topics (Table 1) were initially designated as important for college students to know about Ebolavirus.

The PKSs were revised each time the assessment was revised to more accurately reflect what college students need to know based on the results obtained throughout the study.

Stage 2: Creation, Review, and Revision of Pilot VirEMiA

Creation of Pilot VirEMiA

The initial pilot assessment consisted of twenty multiple choice questions and twenty-one open ended questions based off of the PKSs. Some of the multiple choice questions had more than one correct answer and students were told "You may choose any, all, or none of the answers". Each of the multiple choice questions were followed by an open ended question prompting students to explain why they chose their answer. The last open ended question asked students to write down anything else known about Ebolavirus not covered in the assessment to make sure all misconceptions had been covered.

Table 1. PKSs Required for Understanding Ebola virus.

#	PKSs
1.	Ebola disease is caused by a virus.
2.	Viruses are produced from the assembly of pre-formed components, don't grow or undergo division, and lack the genetic information necessary for energy generation or protein synthesis.
3.	Bacteria are living single celled organisms that contain no nucleus or membrane bound organelles, typically have circular DNA, and can be beneficial or harmful to people.
4.	There are five strains of Ebola virus that have currently been identified.
5.	Four out of the five strains of Ebola can cause EVD in humans.
6.	Ebolavirus symptoms include fever, headache, diarrhea, bleeding, and a cough.
7.	Less than half of the patients with Ebola experience massive blood loss.
8.	Some ways to test if someone is infected with Ebolavirus include testing their blood, performing an autopsy, and testing for antibodies.
9.	You cannot tell if someone is infected with Ebola just by looking at them.
10.	At this time there is no medically proven and FDA approved treatment that neutralizes Ebola. However, there are a few treatments for Ebolavirus undergoing evaluation for FDA approval.
11.	Ways to prevent the spread of Ebolavirus include wearing a surgical mask, avoiding contact with infected dead bodies, avoiding bodily fluids of an infected person, quarantining people suspected of being infected with Ebolavirus, avoiding contact with infected host animals, and washing hands.
12.	Ebola has been confirmed to spread through blood, secretions, and other bodily fluids.
13.	Ebola cannot be spread through mosquitos, the air, or through casual contact like shaking hands.
14.	The average length of time between exposure to Ebola and when symptoms first appear is 2-21 days.
15.	The mortality rate of the 2014/2015 Ebola outbreak is estimated around 51%.
16.	Ebola has a low survival rate.
17.	Ebola causes cell death, shock, and multi-organ failure.
18.	Humans, bats, monkeys, and apes are all able to infect humans with Ebola.
19.	People who have had direct contact with blood or bodily fluids from someone with symptoms through splashes to nose, eye, mouth, break in the skin, or a needlestick are at risk of contracting Ebola.
20.	People who care for someone showing Ebola symptoms, but have not taken precautions to prevent transmission are at risk of contracting Ebola.
21.	Anyone who comes into contact with a person or food from Africa does not have a high risk of contracting EVD.
22.	People are contagious as long as their blood and secretions contain Ebola.
23.	Influenza, HIV/AIDS, and Malaria kill more people on average per year than Ebola.
24.	Anthrax, HIV/AIDS and the H5N1 flu have a lower survival rate than Ebola's 2014/2015 survival rate.
25.	The chances of the average US citizen getting infected with Ebola is almost zero.

Review and Revision of Pilot VirEMiA

The pilot VirEMiA and the final version of VirEMiA were reviewed once by experts in the fields of Ebola research, science education research, vaccine research, and virology professors. The purpose of the first round of review was to evaluate the extent to which the items included in the pilot version of VirEMiA were accurate. In the second round, the experts' review of the assessment was to again assess if the final version was accurate.

All the experts agreed with the category assignments and suggested several minor word changes to make questions and answers more accurate. For example, one question was initially worded as "At this moment, is there a treatment that neutralizes Ebola?". However, one reviewer commented that "Vaccines are licensed; drugs are approved. However FDA often uses the term FDA-approved for both vaccines and drugs.", therefore the question was changed to "At this time, is there a medically proven and FDA approved treatment that neutralizes Ebola?". The pilot version of VirEMiA was revised based on the experts' suggestions.

Stage 3: Initial Data Collection, Analysis, Expert Review, and Revisions

Data Collection

The initial version of VirEMiA was given to 16 science and 14 non-science majors at Wright State University. Students were recruited by having professors forward the link to VirEMiA to their students. Answers were coded in a few different ways based on the type of question and if the correct answer was to select a choice or leave it blank. Incorrect multiple choice responses were scored with a '0'. Correct responses to multiple choice questions with one correct answer were scored with a '1'. Multiple choice

questions with more than one correct answer were scored by each possible choice. For example, question six had five possible choices: If the student correctly selected "A) Fever", it was coded with a '1' and if they failed to select "A) Fever", it was coded with a '0'. However, in questions with answers that are incorrect, like question fourteen answer choice "C) The only way to tell if someone has it is to quarantine them and see if they hemorrhage, and if they do, it is too late to save them", then students who did not select C were coded with a '1' while those who selected it as correct were coded with a '0'. Since open ended questions were used purely to make sure all misconceptions had been covered, they did not receive a score. Rather, the qualitative information these questions provided were used to inform development of the final multiple choice questionnaire.

Validity of VirEMiA

When creating an assessment, it is imperative to show test validity. Test validity was used to make sure the assessment measured what it is supposed to measure and that the assessment actually tested the knowledge that was required to understand the topic of the assessment. Test validity was shown through content and construct validity. Content validity is making sure the items of the assessment are accurate according to an expert. Construct validity is making sure the assessment items actually test the content they are supposed to. Test validity was shown through expert review of the assessment, item p-values, Cronbach's alpha, Rasch model, and principal component analysis.

Item p-values

Item p-values were found by calculating the proportion of students that answered an item correctly (Wollack, 2005). This statistic is also known as the Item Difficulty Index because the higher the p-value, the easier the question is and the lower the p-value

the more difficult the question is. Items were considered difficult if the p-value was less than 0.35 and items were considered easy if the p-value was above 0.85 (Wollack, 2005). A good test should have easier questions that most students got correct, difficult questions that most students got incorrect, and everything in between. There should be no questions that everyone got correct or incorrect, because those questions do not tell anything about the ability of the students. The difficulties should also be evenly spread from the easiest question to the most difficult so that the students' ability is as accurate as possible. If there was a big gap between item difficulties, there would be no way to tell where exactly the student fell in their ability.

Cronbach's Alpha

A Cronbach's alpha value was also calculated for each category individually and for the overall assessment to check the reliability of VirEMiA. Cronbach's alpha measures how well items in an assessment test the same concept, or how closely related items were (IDRE, 2015). The more closely related items were, the better the assessment tests what it was intended to test, which means the better the test validity. It is not considered a statistical test, but rather a coefficient of indicating the precision of the test (IDRE, 2015). Values range from 0-1, with 1 meaning all items are perfectly related (Tavakol & Dennick, 2011). Most researchers agree that in order for an instrument to be considered reliable, it must have alpha values between 0.70 and 0.95 (Tavakol & Dennick, 2011). Cronbach's alpha increases as the number of items or the average inter-item correlation increases (IDRE, 2015). Therefore, the higher the Cronbach's alpha value, the more related the items being tested are, and the better the test validity (IDRE, 2015).

To investigate the effects of individual items on reliability, items were removed one at a time, and the change in Cronbach's alpha was observed. If an item was removed and the reliability improved, then that item was found to have a negative effect on test precision. Therefore, if an alpha value for an item was greater than the alpha value for the assessment as a whole, the reliability of the assessment would have increased if this item was removed. Results from this test was not the only reason an item was removed but was used in conjunction with all other tests described below to decide if an item needed to be removed. This test was used to analyze if VirEMiA is a reliable measure for college students' misconceptions about Ebola and was used to address the first research question.

Rasch Model

Imagine the items of a test fit on a line with high ability to the right and low ability to the left (Figure 2) (Wright & Stone, 1979). Therefore, items that were easy would fall to the left end of the line and items that were difficult would fall toward the right end of the line. A person's ability would also be shown on this line. It would be expected that they would correctly answer any items to the left of their position and miss any questions to their right of their position. This scenario shows how test scores depend as much on the characteristics of the test as the ability of the person taking the test. For example, imagine a person got a perfect on the exam, but all the item difficulties were on the left half of the line. If someone were to just look at the exam score, they would assume the student had mastered the subject. If they were to then look at this line, they would realize the exam did not accurately reflect the ability of the test-taker. A perfect score on a test does not reflect mastery unless the most difficult questions conceivable

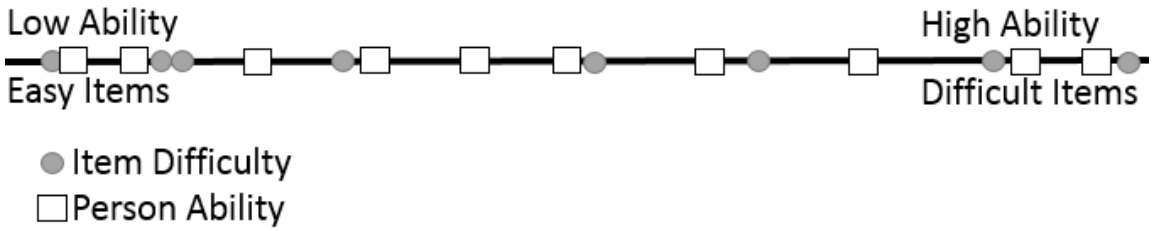

Figure 2. Item and Person Abilities on a Line

had been included in the test and the person had gotten them correct (Wright & Stone, 1979).

The Rasch model calculated the probability a person had of getting an answer correct on a test taking the difficulty of the question into account (Uekawa, 2005). The probability of the person getting an answer correct is based on two predictors, person ability and item difficulty. This method allows the data to reflect the ability of the person while controlling for the difficulty of the item. This means that high ability students should get easy questions correct, and low ability students should miss difficult questions (Uekawa, 2005). Items that have estimates greater than 1.3 underfit the Rasch model, which means the item favors low ability students while items with estimates less than 0.7 overfit the data, which means the item favors high ability students. Items between 0.7 and 1.3 fit the Rasch model and do not favor high or low-ability students.

Based on the Rasch equation, if the ability of a person (v) is greater than the difficulty of the item (l) and their difference is greater than zero $(\beta_v - \delta_l)>0$, then the probability of a correct answer should be greater than half $P|\ X_{vl}=1|>1/2$ (Wright & Stone, 1979). However, if the ability of the person (v) is less than the difficulty level of the item (l) and their difference is less than zero $(\beta_v - \delta_l)<0$, then we want the probability of a correct answer to be less than half $P|\ X_{vl}=1|<1/2$. Finally, when a person's ability (v) is equivalent to the item difficulty so that their difference is zero $(\beta_v - \delta_l)=0$, then the probability of a correct answer is exactly one half $P|\ X_{vl}=1|=1/2$ (Wright & Stone, 1979).

Persons or items with all correct or incorrect values were removed because they did not accurately reflect the difficulty of the item or the ability of the person (Wright & Stone, 1979). Probability values were then converted to logits (log-odds) measures. Item

difficulty increased with the proportion of incorrect responses while person ability increased with the number of correct responses. Standard errors were also calculated through the Rasch model. When person and item values are ordered by correctness, there should be a pattern where there is a series of 1's followed by 0's with the transition from 1's to 0's forming a diagonal across the person and item values. There should not be 1's in the middle of 0's and 0's in the middle of 1's. For people that do not fit the trend, the difference between ability and difficulty should be compared for each question. If the difference is positive, they should get the answer correct and if negative, they should have gotten it wrong. The number of unexpected responses can be tabulated from this analysis. The mean squares fit can then be calculated to determine if a low performing student got a difficult question correct or a high performing student got an easy item incorrect (Wright & Stone, 1979). Item infit and outfit values should be between 0.7 and 1.3 (Bond & Fox, 2007). Fit indices above 1.3 indicate that lower ability students are more likely to get the question correct than high ability students. Fit indices below 0.7 indicates high ability students are more likely to get an item correct than low ability students (Bond & Fox, 2007). When item value ranges are put on a line, items shouldn't overlap (Wright & Stone, 1979). If they do, they represent redundancy analogous to putting two tick marks on a ruler at the same spot. Ideally, the items should be spread relatively equally across the line. Large gaps show a weakness in the assessment that needs to be filled to make sure the test reflects a person's ability as accurately as possible (Wright & Stone, 1979).

Person parameters and item difficulty can be plotted together on a Wright map, named after Ben Wright (one of the authors of "Best Test Design") (Wright & Stone,

1979). Wright maps allow researchers to easily visualize the distribution of person ability and item difficulty. This is a way to visually check that items are evenly spread from easy items to difficult items and that there are no items that everyone should get correct or incorrect. If there are items that everyone should get correct or incorrect, or if there are items at the same spot on the Wright map, researchers must decide if the item is important and should be kept, if it needs to be re-worded to fit the scale better, or if the item should be removed since it does not add any information about person ability (Wright & Stone, 1979).

Residual correlations should be calculated to also determine what items should be removed (Wright & Stone, 1979). A highly positive residual correlation indicates the items have the exact same answer pattern and are getting at the same thing so one of the items may be removed without taking away any information. A highly negative residual correlation indicates the items have opposite answer patterns, meaning if a student got one item correct, they most likely got the other incorrect. This also means a researcher can remove one of the items without losing any information. The last statistic calculated for Rasch is separation reliability. Separation reliability values can range from zero to one, with values above 0.5 being considered acceptable. These reliabilities indicate the precision of items and people on the Rasch scale (Wright & Stone, 1979).

Once all of this was found, the assessment was revised and the analysis was re-run to see if another revision was necessary. Students Certainty of Response Index (CRI) values for all remaining items were then looked at. Four degrees of certainty were used in this assessment: “Complete Guess”, “Uncertain”, “Certain”, and “Very Confident”. For this part of the study, the researcher was only interested in changing correct answers due

to guessing to incorrect since the student does not actually know that information. Therefore, anytime a student answered a question correctly, but indicated guessing, the 1 was changed to a 0 because guessing means they do not know about the subject of the question, so it should be considered wrong (Romine, Schaffer & Barrow, 2013). The Rasch model was then fit to this data. Item estimates and person parameters from the previous Rasch analysis on data that were not CRI-adjusted and the present data were compared to determine if confidence has an effect on students' ability and item difficulty measures. Ideally, while it is expected that students' measures may change, the item difficulty measures should stay relatively similar between the original and CRI-adjusted data.

Principal Component Analysis

Principal component analysis (PCA) on residuals was used to determine if the data was unidimensional, meaning all of the significant variances are described by one Rasch model. Principal component analysis tells how much of the variance in the data is explained by the Rasch model. Data are unidimensional if one factor explains most of the data or the eigenvalue is about 3 (Galli, Chiesi, & Primi, 2008). An eigenvalue is the number that tells how much variance in the data is explained by each component. A component is a group of similar variables combined into a new variable, or component, found using PCA. After PCA was run, loadings were rotated using promax rotation in order to make the loading pattern more pronounced. Residuals were found using the person ability and item difficulty parameters after Rasch analysis. Using excel, an expected value matrix was found by taking e to the person ability parameters (Θ) minus the item difficulty parameters (β) all divided by one plus e to the person ability

parameters (Θ) minus the item difficulty parameters (β) ($expected\ value = \frac{e^{(\theta-\beta)}}{1+e^{(\theta-\beta)}}$). The residuals were then found by taking the expected value minus the actual value.

Revision of VirEMiA

Once all the analysis was completed, items were fixed as described in the results section. After the items were revised, they were sent back to three of the same experts to get content validity evaluated. Based on their suggestions, several items were revised to create the final version of VirEMiA. Some revisions made to the assessment were to remove all "other" answer choices, answer choice "E) Bacteriophage" was removed from item 2 since bacteriophage is a specific type of virus, and therefore, also fits the definition of a virus used for item 2. Answer choice "E) Bacteriophage" was also removed from item 3 to keep the answer choices for item 2 and 3 the same so they can be used to identify if students know the difference between bacteria and viruses (Appendix A). Item 5 "How many strains of Ebola are there?" was changed to "How many strains of Ebola have currently been identified?" to make the question slightly more accurate in that there is a very slight chance there may be strains we are unaware of at this moment. The answer choices were also changed from "1", "2", "3", "4", "5" to "There is only one strain of Ebola", "There are about five strains of Ebola, all of which can cause Ebola disease in people", "There are about five strains of Ebola, most of which can cause Ebola disease in people", and "There are about five strains of Ebola, one of which can cause Ebola disease in people". The answer choices were changed because students indicated guessing, and by changing the point of the question from: How many strains? to Do people know that there are more than one strain and each is slightly different?, misconceptions will be more likely to be found. Item 7 was changed from "How many

Ebola patients bleed out?" to "How many Ebola patients experience massive blood loss?" to make it more clear they are being asked about hemorrhaging without actually using the word hemorrhage incase people do not know what it means. Answer choice "About 90% of patients" in item 7 was lowered to 20% to make the range of answer choices a little more evenly spread between all and none. "Less than half the patients" was changed to about 50% of patients" in item 7 so that the 20% choice is not the only answer choice to have a percent in it, which could influence their answer selection. Item 8 was split up into four true / false questions, "You can tell if someone is infected with Ebola by looking at them.", "You can tell if someone is infected with Ebola by testing their blood", "You can tell if someone is infected with Ebola by performing an autopsy", and "You can tell if someone is infected with Ebola by testing for antibodies". This is to prevent students from randomly clicking the same answer choices, which was suspected given the finding of perfect Rasch residual correlations in each of these choices. "Washing hands" was added as a possible answer choice to item 10 since it is also a means of prevention and some students indicated being unsure if hand washing fell under the answer choice "Quarantine" or if it is another means of prevention that was not mentioned. Item 11 was split into four new true / false items just like item 8. Answer choice "It disables the immune system" from item 14 was changed to "It causes cell death, shock, and multi-organ failure" to make it more clear what Ebola actually does and because people are more likely to understand the new wording than what "disables the immune system" means. "It has a high case/fatality rate" in item 14 was changed to "It has a low survival rate (for example if 100 people get an illness and only 10 survive)" in case people did not understand what a case/fatality rate was. "It is just a myth that Ebola is dangerous" was

also added to item 14 as a distractor that could be a misconception. “None of the above” was added as a distractor to items 15, 18, and 19 and as a possible misconception. “Anthrax” and “HIV/AIDS” were added as answer choices to item 19 since people may know a little bit more about them than the original answer choices “Smallpox”, “Bubonic plague”, and “Rabies”. Also “higher case/fatality rate” in item 20 was changed to “low survival rate (for example if 100 people get an illness and only 10 survive)” again in case people did not know what case/fatality rate meant. The final version of VirEMiA is shown in Appendix B.

Stage 4: Data Collection for Final Version of VirEMiA, Reliability Analysis, and Misconception Analysis

Data Collection

Data were collected from 203 non-science majors at Wright State in a freshman Health and Disease class for non-science majors. 30% of those 203 were male, 72% Caucasian, 20% black, 1% Eskimo/Native American, and 7% other. Of those, 117 took the assessment before and after learning about Ebola in class, while an additional 53 took the assessment only before learning about Ebola and 33 took the assessment only after learning about Ebola. Data were also collected from 97 science and non-science majors in a freshman biology class. 43% of those 98 were male and77% were Caucasian, 14% were Black, 1% was Eskimo/Native American, 3% were Indian and 5% were other. In total there were 348 non-science majors and 46 science majors.

Misconception Analysis

For the Rasch analysis, even if students took the pre-test, post-test scores were treated as different students. For example if Jane took the pre- and post-test, her pre-test

scores would be treated as one person and the post-test scores treated as another instead of having pre- and post-test score together. This was done so Rasch only had to be performed once, and pre- and post-test scores could be compared on the same scale without the need for conversions. Doing this carries that assumption that item functioning does not change significantly between the pre- and post-test. Given the short time duration between the pre- and post-test, this assumption seemed reasonable. Separation reliability was found for the items using the eRM package from R to determine the overall reliability of the assessment in measuring what students do and do not know about Ebola.

Rasch analysis with the coded data and with confidence integrated was performed in the same way as Stage 3. To do the actual misconception analysis the CRI was used in conjunction with VirEMiA to determine if an incorrect answer was due to a lack of knowledge or due to a misconception (Hasan, Bagayoko & Kelley, 1999). The same four degrees of confidence used in stage 3 were used here. While a simple "Did you guess, yes or no" could have been used for Stage 3, the CRI was used in a different way in this stage that required four degrees to be used. For this stage high degree of confidence was important since a high degree of confidence along with an incorrect answer is a misconception. Therefore, four degrees of certainty were used so that the CRI could not only be used to change correct answers due to guessing to incorrect, but also to determine what is a misconception. Low degree of certainty (0-2) suggests guessing which means a lack of knowledge while high degree of certainty (2-4) suggests a high degree of confidence in the answer. To code for misconception analysis, a misconception is an incorrect answer with a CRI greater than two, and anything else is not a misconception

(Table 2). Misconceptions were coded with a 1 while no misconception was coded with a 0. This changed the Rasch model to express the likelihood a student had a misconception, where lower item estimates were more likely to reveal misconceptions. The Wright Map was used as a visual tool for predicting what misconceptions students had. Items at the left end of the Wright Map that are all clustered in a group were those which revealed the greatest number of misconceptions. A distractor analysis was then performed to determine what the exact misconception was. Distractor analysis is done by finding the percent of students that chose each answer choice for an item that had a misconception. This test was used to determine the most persistent misconceptions that college students have and helped answer the second research question.

Difference in Misconceptions between Students with and without a Strong Background in Science

To determine if students with a strong background in science have fewer misconceptions than those without, several two-sample t-tests assuming equal variance were calculated in excel using the misconception coded data. In the first t-test, students with a strong background in science included nursing, pre-med, biomedical engineering, earth and environmental sciences, biology, pre-dentistry, clinical laboratory science, applied physiology, chemistry, and psychology. For the next t-test, students with a strong background in science included all the same majors as the first t-test except for psychology majors. The reason the analysis was run with and without psychology majors was due to the fact that people argue whether psychology is a “hard” or “soft” science (Breckler, 2005). In the third t-test, students with a strong background in science included all the same majors as the first t-test except for nursing majors. The reason the analysis

Table 2. Decision Matrix for Students and for a Given Question Based on Score and CRI

	Low CRI (<2)	High CRI (>2)
Correct	CL: Lack of knowledge (Guess)	CH: Knowledge of correct concepts
Incorrect	WL: Lack of knowledge	WH: Misconception

was run with and without nursing majors is that nursing majors are not required to take sciences classes that are at the same level as science majors, but they do have to take more science classes than most non-science majors and they may have to deal with Ebola patients in the future. In the last t-test, students with a strong background in science included all the same majors as the first t-test except for nursing and psychology majors.

To determine what the misconceptions were that were different between science majors and non-majors, average logit values for science and non-science majors were found. These values were then looked at on the Wright map to determine what items fell between these logit values since these would be the misconceptions science majors did not have but non-science majors did. A distractor analysis partitioned by major/non-major was performed to see which distractors were chosen by majors and which were chosen by non-majors.

Methods for Just In Time Teaching Analysis

Students took the assessment before learning anything about Ebola in class. The data were analyzed to find the p-value for each item. Any items with a p-value with less than 0.5 were emailed to the professors as things the students do not know or may have a misconception about. The professor then spent a 55 minute class period discussing Ebola, focusing on the concepts associated with items with p-values less than 0.5. Four days later, students were given VirEMiA again.

A paired t-test and Cohen's D were used as tests of statistical and practical significance, respectively. The t-value from a t-test is the difference between the means divided by the difference between the standard error (Rumsey, 2011). Standard error will decrease as the population size increases. This means the t-value is completely dependent

on the population size (Rumsey, 2011). Cohen's d is the mean difference divided by the standard deviation (Williams, 2011). This means Cohen's d is independent of the population size and is instead a gain on a scale of standard deviations. It is a good idea to calculate both the t value and Cohen's d value because the t value indicates if the data is statistically significant or not while Cohen's d indicates if the data is practically significant (Williams, 2011). The null hypothesis for the t-tests will be rejected if the confidence level is 95% or above ($p \leq 0.05$).

IV. RESULTS

Pilot VirEMiA Analysis

Summary Statistics

This assessment was given to 16 biology majors and 14 other majors. Of those, only 13 biology majors and 9 other majors finished the assessment. Student 21 only answered two questions and got both incorrect, student 22 only answered the first two questions and got both correct, and student 23 only answered the first question and got it correct (Data not shown). Therefore, all three were removed before analysis was performed. The other students that started the assessment but did not finish, completed at least half of the assessment so they were included in the analysis. Of the 27 students that were included in the analysis, 8 (30%) were male and 19 (70%) were female, 19 (70%) were white, 6 (22%) were black, and 2 (7%) were other ethnicities. Students were recruited from Wright State University. Undergraduate biology majors were recruited from a freshman biology class and a microbiology class for science majors. Other majors were recruited from a freshman biology class and a microbiology class for non-science majors.

Item p-values were calculated for each item (Table 3; Appendix A). The easiest items were 14e, 15f, and 16d with item p-values of 1.00, indicating that all students got them correct. Other items that were easy included items 6a, 6b, 8a, 10b, 10c, 10d, 14d, 16a, and 16b, with p-values between 0.85 and 0.96. The most difficult item was 18d and 18e with an item p-value of 0.18. Other items that were difficult include items 4, 5, 10a,

12, 13, and 19e. Items 14e, 15f, and 16d were removed prior to analysis since 100% of students correctly answered them (Table 3).

A correlation analysis was performed on Stata which showed most items are slightly to moderately correlated. However, item 8f and 8b are strongly correlated (0.73), item 19a and 6b are strongly correlated (0.77), item 14b and 9 are strongly correlated (0.70), and finally item 19c and 19b are strongly correlated (0.70).

Validity

Cronbach's alpha values were also found using Stata. The Cronbach's alpha for the assessment with all 20 questions and options before any items were eliminated was 0.79. This indicates items on my assessment are related and that the assessment is reliable as a whole. According to the results, items 4, 7, 10a, 13,15a, 17, 19b, and 19c don't fit the scale and would improve the reliability of the assessment if they were removed (Table 4). Before any items were removed, more analysis was performed to make sure removing the items would improve the assessment.

Pilot VirEMiA Initial Rasch Analysis

Rasch analysis was performed using the eRm package in R. First, item difficulty logit measures were calculated (Table 5). Most items had infit and oufit values between 0.7 and 1.3. However, items 10a (outfit=1.35), 13 (outfit=1.56), 15a (outfit=1.40), 19b (outfit=1.30), and 19c (outfit=1.57, infit=1.37) all had infit and/or outfit values greater than 1.3, indicating these items underfit the Rasch model and that items favored low-ability students. Item10a (Wearing surgical masks is a means of preventing the spread of Ebola) was initially written to be incorrect because there is no indisputable evidence that

Table 3. Pilot VirEMiA Score and Item P-values

Item	Score	Item p-value
1	25/30	0.83
2	13/29	0.45
3	14/27	0.52
4	9/27	0.33
5	6/27	0.22
6a	26/27	0.96
6b	23/27	0.85
6c	21/27	0.78
6d	19/27	0.70
6e	19/27	0.70
7	11/27	0.41
8a	25/27	0.93
8b	17/27	0.63
8c	10/27	0.37
8d	15/27	0.56
8e	13/27	0.48
8f	17/27	0.63
9	16/25	0.64
10a	5/24	0.21
10b	22/24	0.92
10c	23/24	0.96
10d	23/24	0.96
10e	18/24	0.75
11	18/24	0.75
12	7/22	0.32
13	6/22	0.27
14a	15/22	0.68
14b	15/22	0.68
14c	14/22	0.64
14d	19/22	0.86
14e	22/22	1.00
15a	17/22	0.77
15b	9/22	0.41
15c	12/22	0.55
15d	8/22	0.36
15e	11/22	0.50
15f	22/22	1.00
16a	21/22	0.95
16b	20/22	0.91
16c	16/22	0.73
16d	22/22	1.00
17	8/22	0.36

Table 3. Continued

Item	Score	Item p-value
18a	14/22	0.64
18b	16/22	0.73
18c	13/22	0.59
18d	4/22	0.18
18e	4/22	0.18
19a	16/22	0.73
19b	14/22	0.64
19c	15/22	0.68
19d	12/22	0.55
19e	6/22	0.27
20	8/22	0.36

Table 4. Cronbach's Alpha Values per Item if Removed from Pilot VirEMiA

Item	Alpha
1	0.79
2	0.79
3	0.79
4	0.80
5	0.79
6a	0.79
6b	0.79
6c	0.78
6d	0.78
6e	0.79
7	0.80
8a	0.79
8b	0.78
8c	0.79
8d	0.80
8e	0.79
8f	0.79
9	0.79
10a	0.80
10b	0.79
10c	0.78
10d	0.79
10e	0.79
11	0.79
12	0.79
13	0.81
14a	0.79
14b	0.79
14c	0.78
14d	0.79
15a	0.80
15b	0.79
15c	0.79
15d	0.79
15e	0.79
16a	0.79
16b	0.79
16c	0.79
17	0.80
18a	0.79
18b	0.79
18c	0.79
18d	0.79
18e	0.79
19a	0.79
19b	0.80
19c	0.81
19d	0.79
19e	0.79
20	0.79

Table 5. Item Difficulty Parameters from Initial Pilot VirEMiA Rasch Analysis

Item	Est.	$SE_{Est.}$	Outfit MSQ	Infit MSQ
1	-1.20	0.54	1.05	1.00
2	0.86	0.40	0.94	0.95
3	0.55	0.40	0.99	1.00
4	1.35	0.42	1.26	1.15
5	1.93	0.47	1.07	0.96
6a	-2.73	1.01	**0.57**	0.92
6b	-1.20	0.54	0.83	0.93
6c	-0.69	0.47	**0.64**	0.78
6d	-0.28	0.43	0.71	0.78
6e	-0.28	0.43	1.15	1.11
7	1.02	0.40	1.11	1.05
8a	-1.99	0.73	**0.64**	0.92
8b	0.07	0.41	0.82	0.88
8c	1.18	0.41	0.92	0.93
8d	0.39	0.40	1.27	1.21
8e	0.70	0.40	1.00	1.01
8f	0.07	0.41	0.84	0.89
9	0.05	0.43	0.86	0.89
10a	2.05	0.51	**1.35**	1.14
10b	-1.86	0.74	1.17	0.95
10c	-2.60	1.01	**0.38**	0.86
10d	-2.60	1.01	1.04	1.00
10e	-0.51	0.48	0.87	0.94
11	-0.51	0.48	0.87	0.96
12	1.37	0.47	0.84	0.91
13	1.60	0.49	**1.56**	1.28
14a	-0.23	0.47	1.13	1.07
14b	-0.23	0.47	0.87	0.88
14c	-0.02	0.45	0.79	0.83
14d	-1.35	0.62	1.01	0.92
15a	-0.71	0.51	**1.40**	1.19
15b	0.96	0.44	0.91	0.95
15c	0.38	0.44	0.90	0.89
15d	1.16	0.45	0.92	0.97
15e	0.57	0.44	0.90	0.91
16a	-2.57	1.01	**0.67**	0.95
16b	-1.82	0.74	0.76	0.91
16c	-0.46	0.49	0.98	1.06
17	1.16	0.45	1.17	1.19
18a	-0.02	0.45	0.89	0.93
18b	-0.46	0.49	1.04	1.07
18c	0.18	0.44	0.94	0.96
18d	2.14	0.56	0.90	0.93
18e	2.14	0.56	0.90	0.93
19a	-0.46	0.49	0.93	0.94
19b	-0.02	0.45	**1.30**	1.27
19c	-0.23	0.47	**1.57**	**1.37**
19d	0.38	0.44	1.02	1.02
19e	1.60	0.49	0.77	0.82
20	1.16	0.45	0.94	0.97

Note: Out of bound indices indicated by **bold** font

Ebola is spread through the air so a mask would do nothing. However, it would stop bodily fluids from entering the nose and mouth so if students selected it, it was coded as correct and if a student failed to select it, it was coded as incorrect. Item 13's (What is the mortality rate of the 2014/2015 Ebola outbreak?) incorrect choices were mortality rates of other Ebola outbreaks. The average CRI for this question was 1.9, or uncertain and most of the comments on this item indicated guessing. The distractors in this question were all relatively close in number, which may have been why the CRI for this item indicated guessing. In an attempt to remedy this, incorrect answer choices were more evenly distributed between 0 and 100 percent. Item 15a (Humans are a suspected host or reservoir for Ebola) could have misfit due to students not knowing what host or reservoir means. The question was reworded for the final version of the assessment so it is only testing students' knowledge of what animals possibly transmit the disease, and not what host and reservoir mean. Item 19b (MERS/SARS had a higher case fatality rate than Ebola's 2014/2015 case/fatality rate could have misfit due to students not knowing much about MERS and SARS. This item was kept since MERS and SARS are a huge threat outside of the US and it is the only item that has a lower case/fatality rate than Ebola's 2014/2015 outbreak. In item 19c's (Smallpox had a higher case/fatality rate than Ebola's 2014/2015 case/fatality rate) response section, students indicated that bubonic plague and smallpox are no longer an issue so they did not select them. Therefore items 19c and 19d were changed to Anthrax and HIV/AIDS respectively. Items 6a (outfit=0.57), 6c (outfit=0.64), 8a (outfit=0.64), 10c (outfit=0.38), and 16a (outfit=0.67) all overfit the Rasch model, indicating the items favored high-ability students. Items 6a (Fever is a symptom of Ebola) and 6c (Diarrhea is a symptom of Ebola) were most likely easier for

high-ability students due to low-ability students not understanding the wording. Item 8a (A way to tell if someone is infected with Ebola is by just looking at them) most likely misfit because when people talk about Ebola, they most often mention the hemorrhaging, so students may have thought you can tell if someone has Ebola because they will be hemorrhaging while in reality only half of patients hemorrhage and the most common symptoms of Ebola are the same as many other common illnesses. Items 10c (Avoiding bodily fluids of an infected person is a means of preventing the spread of Ebola) and 16a (People who have had direct contact with blood or bodily fluids from someone with symptoms through splashes to the nose, eye, mouth, break in the skin, or a needlestick is at risk of contracting Ebola) most likely overfit because high-ability know other viruses spread the same way so Ebola may also.

A person-item map was created based on the item and person parameter estimates (Figure 3). Based on the map, everyone is expected to get items 1, 6a, 6b, 6c, 8a, 10b, 10c, 10d, 14d, 15a, 16a, and 16b correct and no one should get items 10a, 18d, and 18e correct, which closely fits with the item p-value results discussed earlier. The Rasch model predicted that everbody should get item 1 (What causes Ebola disease?) correct since it is always referred to as the Ebola virus. This item was kept, however, since five students did get it incorrect and knowing Ebola disease is caused by the Ebola virus is very important for understanding Ebola. Everyone should also get items 6a (Fever is a symptom of Ebola), 6b (Headache is a symptom of Ebola), and 6c (Diarrhea is a symptom of Ebola) correct since all are often talked about and common symptoms of Ebola. Item 8a (You can tell if someone is infected with Ebola by looking at them) may

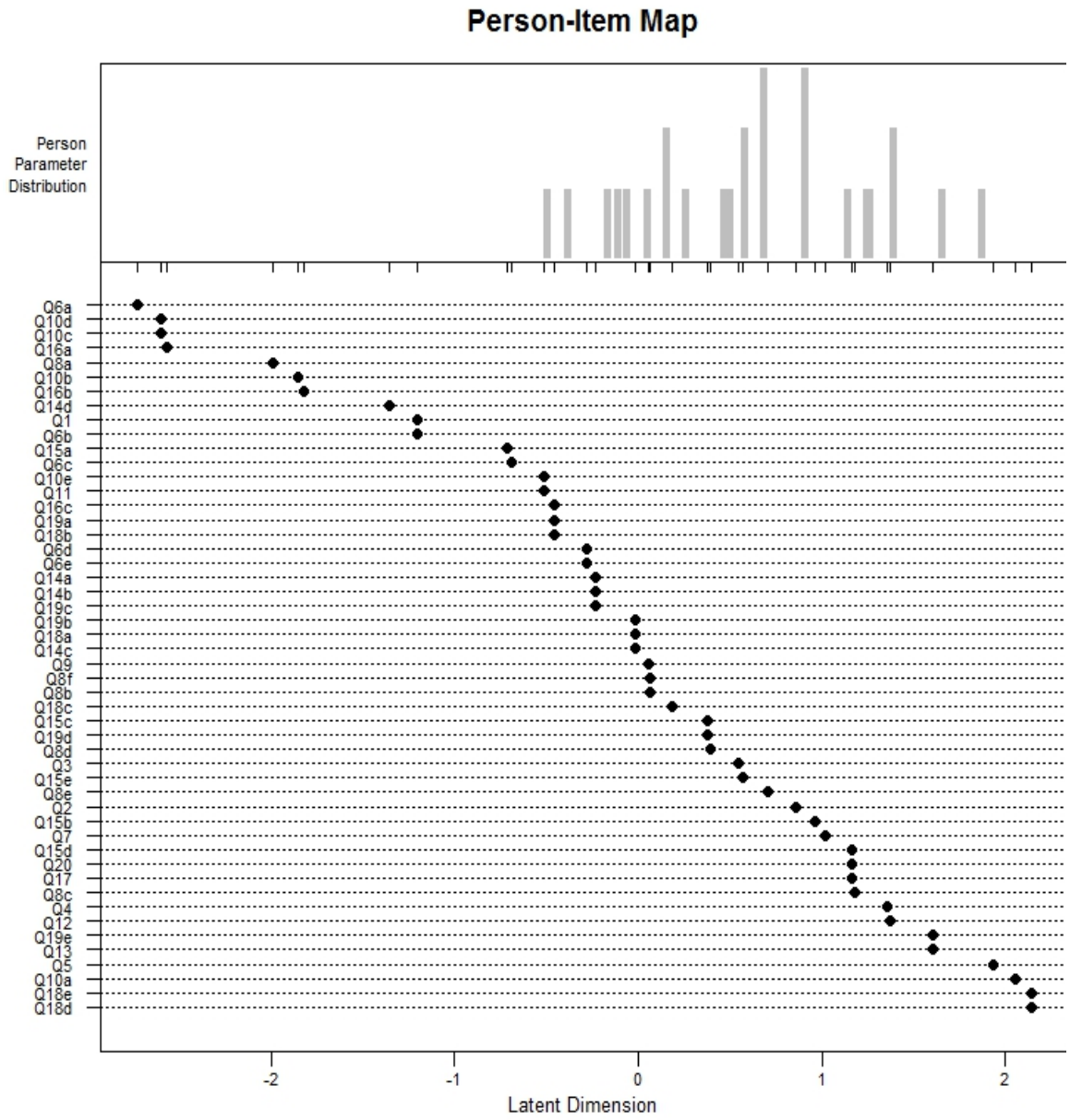

Figure 3. Wright Map from Initial Pilot VirEMiA Rasch Analysis

be an obviously incorrect answer when compared to the other choices, however, with all the panic Ebola caused in the US it is important that people know it is impossible to tell if someone has Ebola disease just by looking at them. Items 10b (avoiding contact with infected dead bodies is a means of preventing the spread of Ebola), 10c (avoiding bodily fluids of an infected person is a means of preventing the spread of Ebola), and 10d (quarantining people who are suspected of being infected is a means of preventing the spread of Ebola) also may be fairly obvious choices, but are imperative in preventing the spread of Ebola. Also, having contact with dead bodies and bodily fluids of an infected person are the two most common ways Ebola is spread by far so it is important people know this, especially if they are healthcare workers that travel to Africa to help. Due to the media, most people do know that Ebola has a high case/fatality rate so it is not surprising that everyone is expected to get item 14d (Ebola is dangerous because it has a high case fatality rate) correct. This item was kept because it is important for people to know all the reasons experts are concerned about Ebola outbreaks. Everyone should know item 15a (Humans are a suspected host/reservoir for Ebola). Item 16a (People who have had direct contact with blood or bodily fluids from someone with symptoms through splashes to the nose, eye, mouth, break in the skin, or a needlestick are at risk of contracting Ebola) and 16b (People who care for someone showing Ebola symptoms, but have not taken precautions to prevent transmission are at risk of contracting Ebola) may be obvious but are also important for people to know about Ebola to help prevent it spreading. People were expected to get 10a (Wearing surgical masks is a means of preventing the spread of Ebola) incorrect because it was initially coded as incorrect as explained above. When Rasch analysis is re-run, this item should no longer be too

difficult. In the explanation section of the assessment, two students mentioned they did not know anything about Dengue which is most likely why everyone is expected to get item 18d (Dengue kills more people on average per year than Ebola) incorrect. One student also mentioned not knowing much about rabies, and another wrote that they thought rabies was cured. Rabies is not common in the US, so people tend not to think about it much, and there is a series of shots if someone is suspected of rabies exposure which is why everyone is expected to get item 19e (Rabies kills more people on average per year than Ebola) incorrect. Separation reliability for people was found to be 0.61 and 0.82 for item. The reliability for people was above acceptable levels but not as reliable as wanted. This was most likely due to the low number of students, and that not all students completed the assessment. Item reliability was good meaning the tick marks along the Wright map were precise, but these are also expected to increase when misfitting items were removed.

Before deciding if any items should be removed, all results were double checked in Bigsteps and residual correlations and principal component analysis was also performed in Bigsteps. All results obtained thus far in R matched the results in Bigsteps. Residual correlations were also found in Bigsteps (Table 6). Based on these results, items 18d and 18e have the exact same answer pattern. Their residuals from the Rasch model are 100% positively correlated, which indicates similar answer patterns in both items. This is not surprising considering that they are the same question but with different viruses and that students mentioned not knowing much about both of them. Items 19b and 19c, 15a and 15c, 15c and 20, 15c and 15d, 8b and 8f, 8c and 8e, and 19c and 19d also had highly positively correlated residuals. It is also not surprising that items 19b and

Table 6. Residual Correlations of Rasch Residuals from Pilot VirEMiA

Correlation	Item	Item
1.00	18d	18e
0.73	19b	19c
0.67	15a	15c
0.66	15c	20
0.65	15c	15d
0.64	8b	8f
0.62	8c	8e
0.60	19c	19d
-0.65	19c	19e
-0.64	10a	10c

19c, 15a and 15c, 15c and 15d, 8b and 8f, 8c and 8e, and 19c and 19d are highly correlated since any item with the same number but a different vowel are different answer choices from the same question. For example item 19b and 19c both ask "Which has a higher case/fatality rate than Ebola's 2014/2015 case/fatality rate?", but 19b is MERS/SARS and 19c is Smallpox. It is unknown why items 15c (Monkeys are a suspected host or reservoir for Ebola) and 20 (What are the chances of the average US citizen getting Ebola?) have similar answer patterns since they are not as obviously related. Items 19c and 19e, and 10a and 10c are highly negatively correlated. Most people have heard of smallpox, know it was terrible to have and that it killed a lot of people while, as previously mentioned, students indicated not knowing much about rabies and indicated they did not think it was a problem today. This could explain why 19c (Smallpox has a higher case/fatality rate than Ebola's 2014/2015 case/fatality rate) and 19e (Rabies has a higher case/fatality rate than Ebola's 2014/2015 case/fatality rate) are negatively correlated. Also as previously mentioned, the coding of 10a was changed after this and should be corrected when Rasch analysis is re-run. Most people know not to come into contact with bodily fluids from someone who is sick, to prevent also getting sick. This could explain why items 10a (Wearing surgical masks is a means of preventing the spread of Ebola) and 10c (Avoiding bodily fluids of an infected person is a means of preventing the spread of Ebola) are negatively correlated.

Principal component analysis on Rasch residuals was also performed using Bigsteps with four components being retained (Table 7). The eigenvalue of the first component was 3.93, which is above Galli, Chiesi, and Primi's value of 3, indicating the scale is not unidimensional (2008). Items were considered important if they had a loading

Table 7. Principal Component Analysis of Initial Pilot VirEMiA

Item	1	2	3	4
Q1	0.06	0.11	0.01	-0.04
Q2	-0.07	-0.19	-0.03	-0.07
Q3	-0.04	-0.18	-0.08	0.08
Q4	-0.01	**-0.3**	0.01	-0.16
Q5	-0.06	-0.12	-0.03	-0.19
Q6a	0.03	0.22	-0.03	0.06
Q6b	0.07	0.23	-0.05	0.14
Q6c	-0.18	**-0.41**	-0.07	0.15
Q6d	-0.25	**-0.69**	-0.05	0.04
Q6e	-0.04	-0.04	-0.04	-0.08
Q7	-0.03	-0.06	-0.05	-0.11
Q8a	-0.15	**-0.55**	-0.03	-0.15
Q8b	0.18	**0.62**	0.06	0.03
Q8c	0.22	**0.78**	0.12	0.13
Q8d	0.2	**0.61**	0.1	0
Q8e	0.2	**0.72**	0.09	0.12
Q8f	0.13	**0.36**	0.06	-0.09
Q9	-0.08	-0.13	-0.02	0.06
Q10a	0.12	0.01	0	**-0.32**
Q10b	-0.12	-0.22	0.01	0.24
Q10c	-0.12	-0.18	-0.01	**0.3**
Q10d	-0.07	-0.07	0.07	0.02
Q10e	-0.14	-0.15	-0.1	0.16
Q11	-0.09	-0.13	0	0.14
Q12	-0.24	-0.01	-0.22	**0.55**
Q13	0.06	-0.07	-0.37	**-0.52**
Q14a	0.3	-0.26	**-0.46**	-0.07
Q14b	**-0.42**	-0.04	-0.24	0.15
Q14c	0.01	-0.07	-0.03	**0.4**
Q14d	0.18	-0.24	-0.25	**0.47**
Q15a	0.24	-0.24	**0.81**	-0.12
Q15b	-0.03	-0.05	**-0.52**	0.23
Q15c	-0.07	-0.27	**0.82**	0.2
Q15d	-0.24	-0.16	**0.52**	0.16
Q15e	-0.06	-0.14	**0.35**	-0.06
Q16a	-0.18	-0.13	0	0.1
Q16b	-0.34	-0.09	**0.34**	0.31
Q16c	0.31	-0.2	0.44	**-0.49**
Q17	0.25	**-0.34**	-0.3	0.07
Q18a	-0.24	0	0	-0.18
Q18b	-0.18	-0.02	0	**-0.39**
Q18c	**-0.63**	0	0.09	0.22
Q18d	**-0.71**	0.06	-0.18	-0.51
Q18e	**-0.71**	0.06	-0.18	-0.51
Q19a	-0.05	-0.01	**-0.43**	0.23
Q19b	**0.77**	-0.36	-0.16	-0.2
Q19c	**0.84**	-0.37	0.08	-0.08
Q19d	**0.64**	-0.24	-0.22	0.04
Q19e	**-0.65**	0.17	-0.25	-0.17
Q20	-0.31	-0.11	**0.72**	0.04

Note: Out significant loadings indicated by **bold** font

Table 8. Initial Pilot VirEMiA Significant PCA Results by Component and Item Loadings

Component	Positive loading items	Negative loading items
1	19c, 19d	14b, 18c, 18d, 18e, 19e
2	8b, 8c, 8d, 8e, 8f	4, 6c, 6d, 8a, 17
3	15a, 15c, 15d, 15e, 16b, 20	14a, 15b, 19a
4	10c, 12, 14c, 14d	10a, 13, 16c, 18b

greater than three or less than negative three. Therefore the items that significantly positively loaded on component 1 were items 19c and 19d while items that significantly negatively loaded on component 1 were items 14b, 18c, 18d, 18e, and 19e (Table 8). Items 19c "Smallpox has a higher case/fatality rate than Ebola's 2014/2015 case/fatality rate", 19d "Bubonic plague has a higher case/fatality rate than Ebola's 2014/2015 case/fatality rate", 14b "Ebola is dangerous because there is no treatment or cure", 18c "Malaria kills more people on average per year than Ebola", 18d "Dengue kills more people on average per year than Ebola", 18e "Rabies kills more people on average per year than Ebola", and 19e "Rabies has a higher case/fatality rate than Ebola's 2014/2015 case/fatality rate" all significantly loaded on the same component because they mostly had to do with comparing other viruses to Ebola and they mostly included viruses that students indicated not knowing much about. The reason items 19c and 19d loaded together was that they had similar answer patterns while items 14b, 18c, 18d, 18e, and 19e also all had similar answer patterns that were the opposite of items 19c and 19d.

Items that significantly positively loaded on component 2 were items 8b, 8c, 8d, 8e, and 8f and items that significantly negatively loaded on component 2 were items 4, 6c, 6d, 8a, and 17. Items 8b "Testing their blood is a way to tell if someone is infected with Ebola", 8c "Autopsy is a way to tell if someone is infected with Ebola", 8d "Quarantine and monitor is a way to tell if someone is infected with Ebola", 8e "Test for antibodies is a way to tell if someone is infected with Ebola", 8f "All are ways to tell if someone is infected with Ebola", 4 "Is a virus alive?", 6c "Diarrhea is a symptom of Ebola", 6d "Bleeding is a symptom of Ebola", 8a "A way to tell if someone is infected with Ebola is by looking at them", and 17 "How long are people contagious with a

virus?" all loaded on component 2 because they all have to do with symptoms, detection, and transmission of Ebola. Items 8b, 8c, 8d, and 8f all loaded together because they had to do with detection of Ebola. Items 4, 6c, 6d, 8a, and 17 all loaded together because they all had to do with symptoms and transmission of Ebola.

Items that significantly positively loaded on component 3 were items 15a, 15c, 15d, 15e, 16b, and 20 and items that significantly negatively loaded on component 3 were items 14a, 15b, and 19a. Items 15a "Humans are a suspected host or reservoir for Ebola", 15c "Monkeys are a suspected host or reservoir for Ebola", 15d "Apes are a suspected host or reservoir for Ebola", 15e "Other are a suspected host or reservoir for Ebola", 16b "people who care for someone showing Ebola symptoms, but have not taken precautions to prevent transmission are at risk of contracting Ebola", 20 "What are the chances of the average US citizen getting infected with Ebola", 14a "Ebola is dangerous because it disables the immune system", 15b "Bats a suspected host or reservoir for Ebola", and 19a "Influenza (H5N1) has a higher case/fatality rate than Ebola's 2014/2015 case/fatality rate" all loaded on component 3 because they all mostly had to do with transmission of Ebola. Items 15a, 15c, 15d, 15e, 16b, and 20 all positively loaded on component 3 because they all had to do with transmission of Ebola. Items 14a, 15b, and 19a all negatively loaded on component 3 because these items had opposite answer patterns that the other answer choices for their items. For example, 15b had opposite answer choices than items 15a, 15c, 15d, and 15e.

Finally, items significantly positively loaded on component 4 were items 10c, 12, 14c, and 14d, while items 10a, 13, 16c, and 18b negatively significantly loaded on component 4. Items 10c "avoiding bodily fluids of an infected person is a means of

preventing the spread of Ebola", 12 "What is the average length of time between exposure to Ebola and when symptoms first appear?", 14c "Ebola is dangerous because the only way to tell if someone has it is to quarantine them and see if they hemorrhage, and if they do, it is too late to save them", 14d "Ebola is dangerous because it has a high case/fatality rate", 10a "wearing surgical masks is a means of preventing the spread of Ebola", 13 "What is the mortality rate of the 2014/2015 Ebola outbreak?", 16c "Anyone who comes into contact with a person or food from Africa is at risk of contracting Ebola", and 18b "HIV/AIDS kills more people on average per year than Ebola" all loaded on component 4 because they did not fit in the other three components.

Based on all the results discussed so far, items 4, 8d, 8f, 15a, 18d, 18e, 19c, 19d, and 19e were removed. Item 4 was removed because it was only included in the pilot version in an attempt to elicit misconceptions about viruses in general in the written explanation section of the assessment. Whether viruses are living or not is still highly debated by scientists, so it cannot be included in the final version of the assessment. Item 8d and 8f were removed because students may have interpreted a different meaning than intended. Item 15a was removed because it misfit the Rasch analysis, 100% of students were expected to get it correct, it was highly correlated with item 15c, and it is obvious humans get Ebola. Item 19c was removed because it misfit the Rasch analysis and was correlated with 19d. Items 18d, 18e, and 19e were removed since students did not seem to know much about Dengue or Rabies and 100% of students were expected to get 18d and 18e incorrect. Items 19c (Smallpox) and 19d (Bubonic plague) were changed since students indicated not knowing much about them and saying they are no longer prevalent

so they were removed from further Rasch analysis. Since some items were removed, Rasch analysis had to be re-run.

Pilot VirEMiA Rasch Analysis Round 2

After eliminating some items in the first round of analysis, the Rasch model fit of the remaining 41 items was explored. Item estimates and fit were re-calculated using R (Table 9). Items 5 (outfit=1.48), 13 (outfit=1.86, infit=1.34), and item 19b (outfit=1.56, infit=1.44) all underfit the Rasch model, indicating guessing, or that items favored low-ability students. Items 6a (outfit=0.64), 6c (outfit=0.56), 6d (outfit=0.64), 8a (outfit=0.66), 10c (outfit=0.24), 16a (outfit=0.53), and 16b (outfit=0.68) overfit the Rasch model, indicating the items favored high-ability students. Even though item 5 (How many strains of Ebola are there?) now misfits the Rasch analysis, it was kept since it is important for people to know that there are different strains of Ebola. Items 6a (Fever is a symptom of Ebola), 6c (Diarrhea is a symptom of Ebola), and 6d (Bleeding is a symptom of Ebola), were all kept since it is important for people to know the symptoms of Ebola. Item 8a (A way to tell if someone is infected with Ebola is by looking at them) was kept because it is important for people to know that you cannot tell if someone is infected with Ebola just by looking at them. Item 10c (Avoiding contact with bodily fluids of an infected person) was kept since it is important for people to know how Ebola spreads and how to avoid getting it, so there will be less panic if there is an Ebola patient in the US again. Item 13 was kept since the mortality of the 2014/2015 outbreak is expected to be a misconception. Also, since the incorrect answer choices were changed, it is expected to have better fit in the final assessment. Items 16a (Influenza has a higher case/fatality rate than Ebola's 2014/2015 case/fatality rate) and 16b (MERS/SARS has a higher

Table 9. Pilot VirEMiA Rasch Round 2 Item Measures and Mean Square Fit Indices for Coded and CRI Integrated Data

	Item Difficulty (SE)		Outfit MSQ		Infit MSQ	
Item	Coded	CRI	Coded	CRI	Coded	CRI
Q1	-0.46 (0.48)	1.13 (0.41)	0.82	1.10	0.91	1.09
Q2	0.81 (0.40)	0.71 (0.42)	0.96	**0.63**	0.96	0.82
Q3	2.25 (0.48)	0.37 (0.41)	0.97	1.07	1.01	1.07
Q5	-2.54 (1.01)	1.89 (0.49)	**1.48**	0.91	1.05	0.96
Q6a	-0.99 (0.55)	-1.95 (0.65)	**0.64**	**4.60**	0.95	1.08
Q6b	-0.46 (0.48)	-0.98 (0.49)	0.82	0.90	0.91	1.29
Q6c	-0.05 (0.44)	-0.54 (0.45)	**0.56**	0.98	0.72	1.03
Q6d	-0.05 (0.44)	-0.15 (0.43)	**0.64**	0.72	0.72	0.89
Q6e	1.30 (0.41)	-0.15 (0.43)	1.13	**0.61**	1.16	0.70
Q7	-1.79 (0.73)	1.66 (0.47)	1.22	**1.50**	1.08	1.19
Q8a	0.31 (0.42)	-1.56 (0.58)	**0.66**	0.80	0.96	0.85
Q8b	1.47 (0.42)	0.20 (0.41)	0.98	**0.61**	1.02	0.81
Q8c	0.97 (0.40)	1.25 (0.44)	0.98	0.90	1.01	0.97
Q8e	0.31 (0.43)	0.71 (0.42)	1.08	1.12	1.12	1.16
Q9	-0.53 (0.52)	0.01 (0.44)	0.79	1.18	0.86	1.25
Q10a	-1.65 (0.74)	-0.49 (0.48)	0.96	**0.67**	1.02	0.76
Q10b	-2.41 (1.01)	-1.34 (0.59)	0.96	0.87	0.87	0.97
Q10c	-2.41 (1.01)	-1.75 (0.67)	**0.24**	0.93	0.75	0.91
Q10d	-0.27 (0.49)	-1.75 (0.67)	1.04	**0.51**	1.02	0.77
Q10e	-0.27 (0.49)	-0.26 (0.46)	0.71	0.95	0.83	**1.34**
Q11	1.65 (0.47)	-0.49 (0.48)	0.81	**0.68**	0.93	0.81
Q12	1.88 (0.49)	1.27 (0.48)	0.75	0.75	0.83	0.92
Q13	0.01 (0.47)	2.91 (0.74)	**1.86**	0.72	**1.34**	0.82
Q14a	0.01 (0.47)	-0.22 (0.47)	1.29	**1.57**	1.13	1.13
Q14b	0.23 (0.46)	-0.45 (0.49)	0.78	1.02	0.85	0.99
Q14c	-1.14 (0.63)	0.00 (0.46)	0.80	0.71	0.83	0.80
Q14d	1.23 (0.45)	-1.31 (0.59)	0.94	0.94	0.84	0.99
Q15b	0.64 (0.44)	1.27 (0.48)	0.87	**0.50**	0.92	0.72
Q15c	1.44 (0.46)	0.63 (0.45)	0.92	0.77	0.91	0.86
Q15d	0.84 (0.44)	1.51 (0.50)	0.86	1.09	0.93	1.09
Q15e	-2.38 (1.01)	0.83 (0.46)	1.02	1.15	1.02	1.15
Q16a	-1.62 (0.74)	-2.26 (0.80)	**0.53**	1.03	0.93	1.08
Q16b	-0.23 (0.49)	-2.26 (0.80)	**0.68**	**0.48**	0.84	0.69
Q16c	1.44 (0.46)	-0.45 (0.49)	1.24	0.73	1.25	0.74
Q17	0.23 (0.46)	1.05 (0.46)	1.17	1.12	1.22	1.15
Q18a	-0.23 (0.49)	0.00 (0.46)	0.91	1.19	0.96	1.25
Q18b	0.44 (0.45)	-0.22 (0.47)	1.12	0.88	1.15	0.97
Q18c	-0.23 (0.49)	0.00 (0.46)	0.86	0.80	0.91	0.88
Q19a	0.23 (0.46)	2.08 (0.56)	0.89	0.86	0.94	0.92
Q19b	1.44 (0.46)	-0.22 (0.47)	**1.56**	0.98	**1.44**	0.97
Q20	1.13 (0.41)	0.63 (0.45)	0.96	1.03	1.01	1.10

Note: Out of bound indices indicated by **bold** font

case/fatality rate than Ebola's 2014/2015 case/fatality rate) were kept because there is a lot of fear around Ebola due to there being no vaccine currently and the symptoms, so it is important to remind people that Ebola is actually less likely to kill you than most other viruses in the US. Item 19b (MERS/SARS has a higher case fatality rate than Ebola's 2014/2015 case/fatality rate) was kept since it is the only incorrect answer in that set and SARS/MERS is a serious threat outside of the US.

Most of the twenty-seven students in the pilot study indicated in response sections that they had learned about Ebola in a class. The final version of VirEMiA was given much sooner in the semester so that students hopefully will not have learned about Ebola in class. By taking the assessment after learning about Ebola, some misconceptions they had may have been addressed and remedied before taking the assessment and their confidence in their answers may be higher than what they would have been if they took the assessment before learning about Ebola in class. Both of these would greatly influence their CRI values and any analysis to determine what is a misconception. By doing this, it is expected not as many items will have such low item estimates. For this reason, none of those items were removed. Separation reliability was found to be 0.69 for person and 0.80 for item. Person reliability did increase after misfitting items were removed, however person reliability slightly decreased. Item reliability was still at a good level indicating the assessment is very reliable and was expected to increase in the final round of data collection when there were more students. To determine if confidence had any effect on the results, CRI values were integrated with scores and another Rasch analysis was run.

Rasch Analysis with CRI Values Integrated

Item fit and estimates for the pilot data with CRI values integrated were calculated using R (Table 9). Items 6a (outfit=4.60), 7 (outfit=1.50), 10e (infit=1.34), 14a (outfit=1.57) all underfit the Rasch model. Items 2 (outfit=0.63), 6e (outfit=0.61), 8b (outfit=0.61), 10a (outfit=0.67), 10d (outfit=0.51), 11 (outfit=0.68), 15b (outfit=0.50), 16b (outfit=0.48) all overfit the Rasch model. Separation reliability for people was 0.82 and 0.80 for item. This indicates the assessment is very reliable when confidence is integrated.

PCA analysis had a first eigenvalue of 6.37, so the scale was not unidimensional. Items that positively loaded on component 1 include items 1, 10b, 10c, 10d, and 18e (Table 10, 11) and no items negatively loaded on component 1. Items 1, 10b, 10c, 10d, and 18e were about Ebola, prevention, and how rabies kills more people on average per year than Ebola. Items that positively loaded on component 2 include item 15c while items 6a and 6b negatively loaded on component 2. Item 15c positively loaded on item 2 because it is an obviously correct answer about the host or reservoir for Ebola while items 6a and 6b are obvious correct symptoms for Ebola, which is why they loaded on the same component but opposite. Item 6d positively loaded on component 3 while item 16c negatively loaded on component 3. Item 6d, "bleeding is a symptom of Ebola" loaded the opposite of item 16c "Anyone who comes into contact with people or food from Africa is at risk of contracting Ebola" loaded together because they are both obvious answers, but loaded opposite because 6d is a correct response while item 16c is a distractor. Finally, items 2 and 19a positively loaded on component 4, while items 8b, 8c, and 8e negatively loaded on component 4. Items 2, 19a, 8b, 8c, and 8d all had to do with the definition of a virus, the flu having a higher case fatality rate than Ebola's 2014/2015

case/fatality rate, and detecting Ebola. Items 2 and 19a loaded together because they had opposite answer patterns than items 8b, 8c, and 8d.

These results were all different than the results obtained with just the data and no CRI integration. This indicates confidence does have an effect on students' answers. Items that fit the Rasch model before and after CRI integration mean confidence does not favor low or high-ability students. Low-ability students were favored with confidence when items that fit the Rasch model without confidence then underfit the Rasch model when confidence was integrated, or overfit the model before but fit the model after confidence was added, or overfit the model before and underfit the model after. This includes items 6a, 6c, 6d, 7, 8a, 10c, 10e, 14a, and 16a. Items that underfit the Rasch model, then fit the Rasch model when CRI was integrated, such as items 5, 13, and 19b, means the validity of the items was effected by guessing, but was corrected when CRI was integrated. Items 2, 6e, 8b, 10a, 10d, 11, and 15b fit the Rasch model then overfit the Rasch model when confidence was added. This indicates that students with high- ability were more confident in their answer than low-ability students. Item 16b overfit before and after confidence was integrated. This indicates the wording of the question may be complex and that high-ability students were more confident in their answer than low-ability students. Even though not all items fit perfectly, no items were removed because all remaining items were deemed important.

Figure 4 shows a comparative person and item measure distributions for estimates from the second round of Rasch analysis and from the second round of Rasch analysis after CRI was integrated. This allows visualization of how confidence influence person

Table 10. PCA of Pilot VirEMiA Rasch Residuals with CRI Values Integrated

Item	1	2	3	4
Q1	**0.31**	0.14	-0.10	0.06
Q2	-0.07	0.05	-0.21	**0.32**
Q3	0.09	-0.25	0.00	-0.08
Q5	0.02	-0.10	-0.04	0.04
Q6a	0.00	**-0.32**	0.05	0.17
Q6b	-0.02	**-0.34**	-0.02	0.09
Q6c	-0.05	-0.23	0.28	-0.03
Q6d	-0.07	-0.01	**0.39**	0.09
Q6e	-0.11	-0.29	-0.08	0.25
Q7	0.06	-0.08	-0.11	-0.17
Q8a	-0.05	0.15	0.06	0.12
Q8b	-0.01	0.08	0.00	**-0.43**
Q8c	-0.02	0.10	-0.19	**-0.35**
Q8e	-0.05	0.01	-0.16	**-0.33**
Q9	0.13	0.10	0.26	0.12
Q10a	0.26	-0.06	-0.09	0.24
Q10b	**0.40**	0.00	0.02	-0.02
Q10c	**0.40**	0.00	0.03	-0.02
Q10d	**0.33**	0.02	-0.09	0.10
Q10e	0.13	-0.17	0.15	-0.02
Q11	0.04	-0.06	0.15	-0.05
Q12	0.05	-0.12	0.10	0.05
Q13	-0.21	0.05	-0.16	0.02
Q14a	0.00	0.00	0.18	-0.08
Q14b	-0.05	0.06	0.08	0.16
Q14c	-0.16	0.04	0.14	-0.26
Q14d	-0.17	0.28	0.11	0.11
Q15b	-0.28	0.10	0.00	0.24
Q15c	0.03	**0.36**	0.02	0.02
Q15d	0.00	0.12	0.25	-0.17
Q15e	0.10	0.16	-0.15	0.10
Q16a	0.09	0.25	-0.08	-0.06
Q16b	-0.12	0.02	0.22	0.08
Q16c	-0.01	0.00	**-0.41**	0.04
Q17	-0.26	-0.14	-0.14	0.00
Q18a	-0.14	0.12	0.05	-0.02
Q18b	-0.18	-0.18	-0.24	-0.06
Q18c	0.00	0.28	-0.06	-0.12
Q18e	**0.31**	0.14	-0.10	0.06
Q19a	-0.07	0.05	-0.21	**0.32**
Q19b	0.09	-0.25	0.00	-0.08
Q20	0.02	-0.10	-0.04	0.04

Note: Out significant loadings indicated by **bold** font

Table 11. Pilot VirEMiA Significant PCA Results by Component and Item Loadings with CRI

Component	Positive loading items	Negative loading items
1	1, 10b, 10c, 10d, 18e	
2	15c	6a, 6b
3	6d	16c
4	2, 19a	8b, 8c, 8e

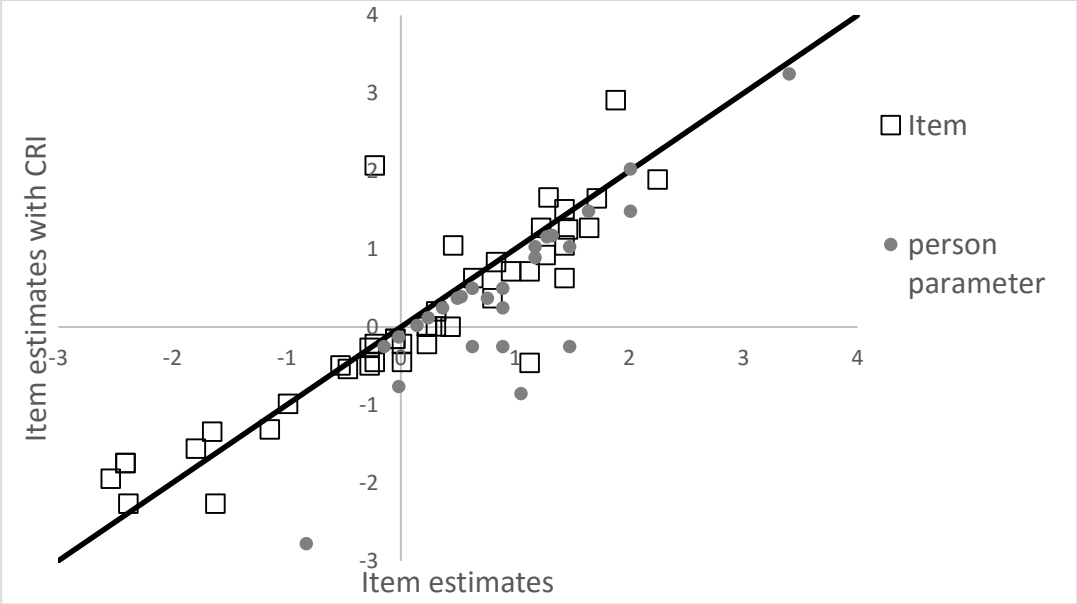

Figure 4. Person and Item Estimates Comparing Pilot VirEMiA Rasch Data With and Without CRI Integrated

and item estimates. This shows confidence did have a slight effect on person and item estimates, but not much.

Rasch Analysis Final Version of VirEMiA

Rasch Analysis with Coded Data Only

Data were collected from 203 non-science majors at Wright State in a freshman Health and Disease class for non-science majors. 30% of those 203 were male, 72% Caucasian, 20% black, 1% Eskimo/Native American, and 7% other. Of those, 117 took the assessment before and after learning about Ebola in class, while an additional 53 took the assessment only before learning about Ebola and 33 took the assessment only after learning about Ebola. Data were also collected from 97 science and non-science majors in a freshman biology class. 43% of those 98 were male and77% were Caucasian, 14% were Black, 1% was Eskimo/Native American, 3% were Indian and 5% were other. In total there was 348 non-science majors and 46 science majors.

Most items fit the Rasch model well (Table 12). Items 12c (outfit=0.57) and 19e (outfit=0.68) overfit the Rasch model while item 24b (outfit=1.34) underfits the Rasch model. Item 12c, “Avoiding bodily fluids of an infected person is a means of preventing the spread of Ebola” may be easier for high-ability students because low-ability students may think this is too obvious, or that it is a distractor. Item 19e, “It is just a myth that Ebola is dangerous” may be too obvious as an incorrect answer for high-ability students. Finally, 24b, “MERS/SARS has a lower survival rate than Ebola’s 2014/2015 survival rate” may be easier for low ability students because they do not know much about MERS and SARS so they do not select it. The separation reliability for person estimates was 0.73, which is lower than wanted. The separation reliability for the items was 0.98, which

indicates the assessment was very reliable for use. PCA was performed on Bigsteps to determine if the data are unidimensional. An eigenvalue of 2.64 was obtained for factor 1, indicating the scale was unidimensional.

Rasch Analysis with CRI Integrated

Most items fit the Rasch model with the CRI integrated (Table 12). Items 1 (outfit=1.36), 2 (outfit=1.67), 3 (outfit=1.79), 4 (outfit=1.32), 5e (outfit=1.31), and 22 (outfit=1.49) all fit the Rasch model with the coded data but underfit the model when CRI was integrated which indicates confidence is favored by low-ability students. The reason high ability students may have been less confident in their answers to these items was due to them overthinking them since these items are easy such as "What causes Ebola disease" and "Cough is a symptom of Ebola". Items 12c (outfit=0.48) and 19e (outfit=0.66) overfit the Rasch model with coded data and with CRI integrated, indicating the wording of the items may favor high ability students and/or high-ability students have more confidence in their answers than low-ability students. Items 16 (outfit=0.69), 20f (outfit=0.66), and 23d (outfit=0.62) all fit the Rasch model with coded data but overfit the Rasch model with CRI integrated, indicating high-ability students have more confidence on these items than low-ability students. All of these items required students to have a little bit of knowledge about viruses such as transmission of Ebola, and the death rates of other viruses. Unless a student has taken a health class that discusses the death rates of various viruses or has taken a class that discusses viruses for more than one day, students most likely would not be confident in their answers. The students most likely to have learned about viruses in the past are science majors, who would be more confident and have a higher ability to answer items correctly since they know more about not just viruses, but

also health and diseases. Finally, item 24b underfit the Rasch model with coded data but fit the Rasch model with CRI integrated, indicating the validity of this item is effected by guessing, which was corrected when confidence was integrated. The item separation reliability for the Rasch model with CRI integrated was 0.98, while the person separation reliability was 0.92. PCA was performed on Bigsteps, with an eigenvalue of 3.13 indicating the data are reasonably unidimensional. The eigenvalue increased when confidence was integrated because the variance was decreased when guessing was eliminated. When item and person estimates for the coded data and data with CRI integrated were plotted against each other, it became clear confidence had a significant effect on the person estimates but not on the item estimates (Figure 5). The effect was a lot more items misfit the Rasch model.

Misconception Rasch Analysis

Most items fit the Rasch model with the CRI integrated (Table 12). Items 2 (outfit=1.55), 7 (outfit=1.31), 8 (outfit=1.61), 9 (outfit=1.54), 10 (outfit=1.83), 19d (outfit=1.36), and 24b (outfit=1.58) all underfit the Rasch model. Items 5a (outfit=0.61), 5d (outfit=0.69), 12a (outfit=0.59), 12b (outfit=0.64), 12c (outfit=0.43), 12d (outfit=0.63), 12e (outfit=0.56), 12f (outfit=0.45), 16 (outfit=0.34), 19e (outfit=0.69), 20c (outfit=0.67), 21b (outfit=0.57), 23a (outfit=0.67), 23b (outfit=0.67), and 23d (outfit=0.40) all overfit the Rasch model. The separation reliability for the items was 0.97 and for the person estimates was 0.86.

Based on the Wright Map, students had misconceptions about items 2, 4, 6, 17, 18, 24a, 24c, and 24d (Figure 6). Most of the students got that “Virus” is the correct answer for item 2 “_____ are produced from the assembly of pre-formed components,

Table 12. Rasch Item Fit and Estimates for Coded, CRI Integrated, and Misconception Data

	Item Difficulty Measures (SE)			MSQ Outfit Measures			MSQ Infit Measures		
Item	Raw	CRI	Misc.	Raw	CRI	Misc.	Raw	CRI	Misc.
Q1	0.12 (0.13)	-0.34 (0.13)	-0.58 (0.15)	0.98	**1.36**	1.15	1.00	1.12	1.07
Q2	1.08 (0.12)	0.85 (0.12)	-1.48 (0.13)	0.96	**1.67**	**1.55**	0.97	1.07	1.25
Q3	1.66 (0.12)	1.33 (0.13)	-0.05 (0.17)	1.11	**1.79**	1.25	1.08	1.21	1.08
Q4	2.32 (0.13)	2.38 (0.15)	-1.86 (0.13)	1.19	**1.32**	1.08	1.10	1.12	1.05
Q5a	-2.24 (0.28)	-1.47 (0.17)	2.31 (0.41)	0.97	0.81	**0.61**	0.97	0.96	0.98
Q5b	-0.13 (0.13)	-0.30 (0.13)	0.21 (0.18)	0.96	1.00	0.81	0.99	1.01	0.98
Q5c	-0.48 (0.15)	-0.54 (0.14)	0.35 (0.19)	0.97	0.99	0.84	0.98	0.99	0.93
Q5d	-0.32 (0.14)	-0.45 (0.13)	0.12 (0.17)	0.86	0.86	**0.69**	0.94	0.93	0.88
Q5e	0.74 (0.12)	0.55 (0.12)	-0.11 (0.16)	1.11	**1.31**	0.88	1.10	1.21	0.93
Q6	1.76 (0.12)	1.94 (0.14)	-1.69 (0.13)	1.09	1.07	0.99	1.07	1.03	1.02
Q7	-1.05 (0.17)	-1.22 (0.16	0.90 (0.23)	1.05	1.16	**1.31**	1.01	1.12	1.07
Q8	-1.95 (0.25)	-1.73 (0.18)	1.67 (0.31)	0.91	1.06	**1.61**	0.99	1.18	1.06
Q9	-0.42 (0.14)	-0.25 (0.13)	-0.03 (0.17)	0.99	1.06	**1.54**	1.00	1.03	1.05
Q10	0.28 (0.12)	0.42 (0.12)	-0.66 (0.14)	1.19	1.20	**1.83**	1.13	1.17	1.24
Q11	0.23 (0.12)	0.21 (0.12)	-0.58 (0.15)	0.91	0.91	1.07	0.96	0.97	1.07
Q12a	0.12 (0.13)	-0.23 (0.13)	0.42 (0.19)	1.03	1.07	**0.59**	0.99	1.04	0.90
Q12b	-0.53 (0.15)	-0.93 (0.15)	0.62 0.20)	0.77	0.79	**0.64**	0.88	0.87	0.86
Q12c	-1.72 (0.23)	-1.84 (0.19)	1.48 (0.29)	**0.57**	**0.48**	**0.43**	0.87	0.73	0.87
Q12d	-0.90 (0.17)	-1.10 (0.15)	0.90 (0.23)	0.90	0.81	**0.63**	0.92	0.84	0.90
Q12e	-0.48 (0.15)	-0.80 (0.14)	0.66 (0.21)	0.74	0.74	**0.56**	0.86	0.84	0.88
Q12f	-1.18 (0.18)	-1.42 (0.17)	1.40 (0.28)	0.75	0.74	**0.45**	0.90	0.85	0.86
Q13	-0.09 (0.13)	-0.34 (0.13)	0.03 (0.17)	0.94	1.13	0.83	1.00	1.04	1.01
Q14	0.47 (0.12)	0.16 (0.12)	-0.26 (0.16)	0.90	0.98	0.94	0.94	0.95	0.98
Q15	0.57 (0.12)	0.28 (0.12)	0.00 (0.17)	1.19	1.19	1.12	1.15	1.16	1.09
Q16	-2.32 (0.29)	-2.37 (0.23)	2.31 (0.41)	0.66	**0.69**	**0.34**	0.94	0.88	0.92
Q17	1.49 (0.12)	1.17 (0.12)	-1.57 (0.13)	0.89	0.90	0.80	0.91	0.90	0.87
Q18	1.63 (0.12)	1.50 (0.13)	-1.82 (0.13)	1.10	1.09	1.17	1.01	1.04	1.05
Q19a	-0.59 (0.15)	-0.37 (0.13)	0.35 (0.19)	0.88	0.85	0.90	0.93	0.91	0.93
Q19b	0.39 (0.12)	0.34 (0.12)	-0.74 (0.14)	0.94	0.88	0.93	0.97	0.95	1.01
Q19c	0.70 (0.12)	0.75 (0.12)	-0.58 (0.15)	1.12	1.01	0.89	1.11	1.03	1.01
Q19d	0.77 (0.12)	0.82 (0.12)	-0.72 (0.14)	1.25	1.22	**1.36**	1.19	1.23	1.16
Q19e	-1.95 (0.25)	-0.87 (0.15)	2.01 (0.36)	**0.68**	**0.66**	**0.69**	0.89	0.82	0.87
Q20a	-0.15 (0.13)	-0.10 (0.13)	0.46 (0.19)	0.98	0.94	0.89	1.00	0.98	1.00
Q20b	0.63 (0.12)	0.42 (0.12)	-0.86 (0.14)	0.87	0.71	0.73	0.90	0.79	0.87
Q20c	0.83 (0.12)	0.57 (0.12)	-0.72 (0.14)	0.87	0.82	**0.67**	0.90	0.87	0.85
Q20d	1.55 (0.12)	1.29 (0.12)	-1.05 (0.14)	0.93	0.89	0.74	0.95	0.96	0.86
Q20e	0.47 (0.12)	0.25 (0.12)	-0.64 (0.14)	0.88	0.78	0.77	0.92	0.85	0.92
Q20f	-3.04 (0.41)	-1.33 (0.16)	2.31 (0.41)	1.06	**0.66**	0.81	0.94	0.85	0.92
Q21a	-1.28 (0.19)	-1.36 (0.17)	1.12 (0.25)	0.73	0.70	0.82	0.91	0.91	0.90
Q21b	-0.62 (0.15)	-0.87 (0.15)	0.90 (0.23)	0.81	0.83	**0.57**	0.88	0.89	0.94
Q21c	-0.59 (0.15)	-0.82 (0.15)	0.85 (0.22)	1.14	1.15	0.82	1.04	1.07	0.98
Q22	1.08 (0.12)	0.97 (0.12)	-0.76 (0.14)	1.16	**1.49**	1.00	1.13	1.24	1.09
Q23a	0.44 (0.12)	0.16 (0.12)	-0.24 (0.16)	0.86	0.78	**0.67**	0.91	0.87	0.89
Q23b	0.81 (0.12)	0.61 (0.12)	-0.26 (0.16)	0.94	0.90	**0.67**	0.96	0.97	0.88
Q23c	-0.13 (0.13)	-0.37 (0.13)	0.12 (0.17)	0.95	0.98	0.74	0.98	1.03	0.93
Q23d	-2.24 (0.28)	-1.47 (0.17)	2.15 (0.38)	0.71	**0.62**	**0.40**	0.90	0.83	0.87
Q24a	1.58 (0.12)	1.64 (0.13)	-1.96 (0.13)	0.96	0.87	1.02	0.97	0.93	1.03
Q24b	0.50 (0.12)	0.85 (0.12)	-0.86 (0.14)	**1.34**	1.29	**1.58**	1.24	1.18	1.30
Q24c	1.55 (0.12)	1.74 (0.13)	-1.74 (0.13)	1.09	1.12	1.16	1.05	1.04	1.15

Table 12. Continued

Q24d	1.22 (0.12)	1.33 (0.13)	-1.56 (0.13)	1.03	1.04	0.97	1.02	0.99	1.04
Q24e	-1.32 (0.19)	-0.02 (0.13)	1.01 (0.24)	1.02	0.92	0.90	0.98	0.97	1.01
Q25	0.73 (0.12)	0.37 (0.12)	-1.22 (0.13)	0.90	0.88	0.79	0.92	0.93	0.88

Note: Out of bound indices indicated by **bold** font

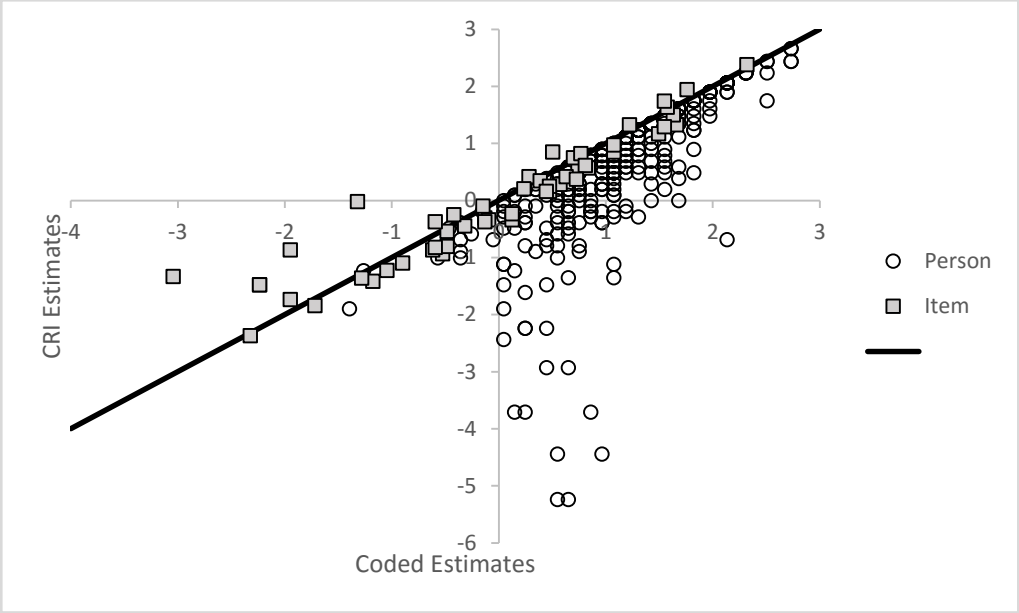

Figure 5. Person and Item Estimates Comparing Final VirEMiA Rasch Data With and Without CRI Integrated

don't grow or undergo division, and lack the genetic information necessary for energy generation or protein synthesis". However, almost a quarter of them had the misconception that the correct answer was "Prokaryote". Almost half of the students had the misconception that there are about five strains of Ebola, one of which can cause Ebola disease in people. Another common misconception was that about 20% of patients experience massive blood loss. Students also had the misconception that the average length of time between exposure to Ebola and when symptoms first appear (incubation period) is 2-10 days. A quarter of students also had the misconception that the mortality rate of the 2014/2015 Ebola outbreak was 73%. The last two misconceptions were that Ebola has a lower survival rate than influenza and anthrax.

Difference in Misconceptions between Students with and without a Strong Background in Science

When psychology and nursing majors were included in students with a strong background in science, the difference in misconceptions between students with and without a strong background in biology was not statistically or practically significant ($t_{df=392}$=1.86, p=0.06, d=0.19). When psychology majors were not considered to have a strong background in science, there was a statistically significant but not a practically significant difference in misconceptions between students with and without a strong science background ($t_{df=392}$=2.28, p=0.02, d=0.24). When nursing majors were not considered to have a strong background in science, there was a statistically significant but not a practically significant difference in misconceptions between students with and without a strong science background ($t_{df=392}$=2.71, p=0.01, d=0.33). Finally, when nursing

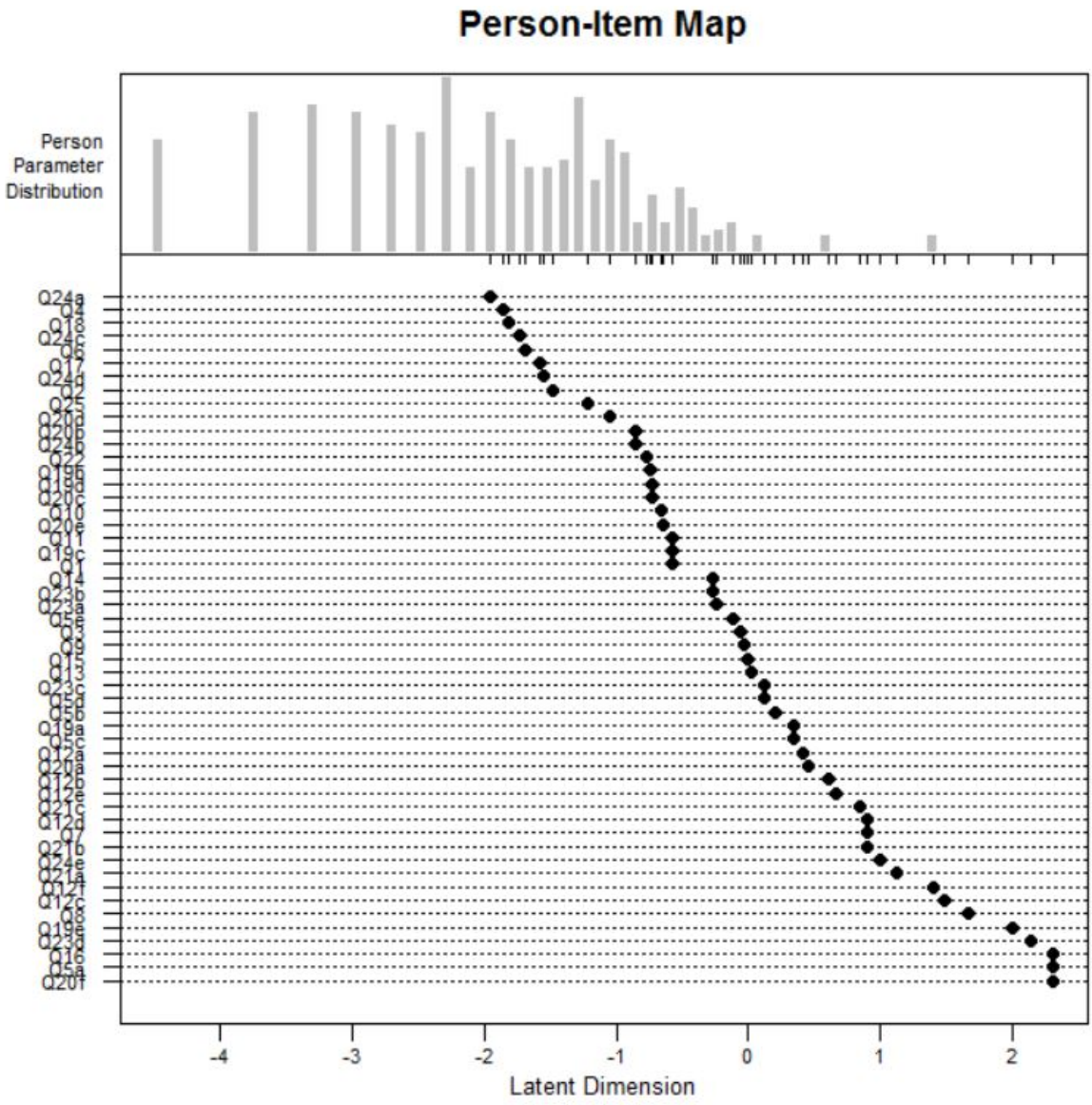

Figure 6. Wright Map of Rasch Misconception Scale

and psychology majors were not considered to have a strong background in science, there was a statistically and practically significant difference in misconceptions between students with and without a strong science background ($t_{df=392}$=4.18, p<<0.001, d=0.64).

The average logit values for science majors (-3.17) and non-science majors (-2.35) was found and compared to the Wright Map. When compared to the Wright map, it was found both averages were below (to the left) of any of the item logits.

Just In Time Teaching Analysis

The reliability for the pre-test using responses not corrected for confidence was 0.75 and the alpha for the post-test using coded data was 0.79. According to the t-test and Cohen's D, students got about 4.4 more questions on the post-test correct compared to the pre-test, and the difference in their scores is statistically and practically significant ($t_{df=116}$=9.11; p<<0.001; d=0.84). The pre- post-assessment Cronbach's alpha values greatly increased when CRI was integrated (pre=0.91; post=0.84). There was still a statistically and practically significant difference between pre- and post-assessment values, with students gaining an average of 9 more questions correct after learning about Ebola ($t_{df=116}$=7.87; p<<0.001; d=0.73). Finally, the pre- post-assessment Cronbach's alpha values for the misconception analysis were 0.81 and 0.83, respectively. Students had about 7 fewer misconceptions after learning about Ebola, and this difference was practically and statistically significant ($t_{df=116}$=-9.80; p<<0.01; d=-0.91).

V. DISCUSSION

The following research questions were addressed in this study:

1. To what extent is this questionnaire a valid and reliable measure for college students' misconceptions about Ebola?
2. What are some misconceptions college students have about Ebolavirus?
3. Is there a difference in misconceptions between science majors and other majors?
4. Does just in time teaching increase students' knowledge about Ebola?

VirEMiA Reliability

The initial version of VirEMiA was above the 0.7 threshold to be considered reliable. However, several items misfit the Rasch model, and two items were only included in an attempt to discover any other possible misconceptions in the short answer part. Therefore several items were removed and re-worded to improve the reliability and fit of the items. Rasch analysis was then re-run to determine if the changes made to the assessment did improve the reliability and fit of the items. The reliability and fit did improve after the first revision. Even though not all items perfectly fit the Rasch model, no further items were removed because the misfitting items were still important to make sure students knew about Ebola. Also, some of the misfit could have been due to the small sample size. VirEMiA was then sent to content experts to make sure the assessment had good content validity. Once the content reliability was fixed, new data had to be collected and Rash analysis and Cronbach's alpha were used to show the final version of VirEMiA to be a reliable assessment for measuring knowledge

about Ebola, misconceptions about Ebola, and if JiTT has an effect on students' knowledge and misconceptions about Ebola. Guessing was shown to have a significant effect on the reliability of the assessment, which is not surprising. After the data were recoded so that correct answers due to guessing were changed to incorrect, the reliability of the assessment greatly improved. Therefore, if the assessment is used in the future, researchers should consider including the CRI for each item and integrate those values with the data to get more accurate and reliable results.

These results show VirEMiA has construct and content validity, as well as reliability. An assessment that is valid and reliable means the assessment can be used to accurately and consistently measure not only students' knowledge of Ebola, but also their misconceptions. Also, by validating VirEMiA with data from students before and after learning about Ebola, using it as pre-homework in a classroom utilizing JiTT, and with students with and without a strong science background, it has been shown VirEMiA can be used in a variety of ways with valid and reliable results. However, VirEMiA has only been validated with college students and while the researcher hypothesizes that VirEMiA will be valid and reliable with other populations, if a researcher wishes to use VirEMiA with younger students, or in the general population, they should calculate the validity and reliability of their data. A couple future questions that could be done using VirEMiA are: (1) what misconceptions do the general population in the United States have about Ebola and (2) do people in other developed countries have the same misconceptions that people in the US have?

Ebola Virus Misconceptions

There have been numerous studies performed in the past to determine what misconceptions students have about different viruses (Romine, Barrow, & Folk, 2013; DiClemente, Zorn, & Temoshok, 1986; Ramirez et al, 1997). However, VirEMiA was the first assessment for Ebola misconception analysis in the US and also the first to look at college student misconceptions on Ebola. VirEMiA identified several misconceptions about Ebola and one about the definition of a virus. It was not surprising that students had a misconception about the definition of a virus (Item 2) because scientists still argue over whether viruses are living or non-living (Gortner, 1938; Villarreal, 2008; Milliken, 2015) and depending on their view, the definition of a virus may vary slightly. Also a study recently done by the World Health Organization showed people do not understand viruses and how they work (WHO, 2015). The fact that scientists still argue may intimidate teachers, causing them to not teach about viruses unless necessary. I did not learn about viruses in detail until graduate school, and even then not until I took virology. The definition used in this study was one that should not matter if people consider viruses living or not however and this does not mean teachers should not be concerned that students have a misconception about the definition of a virus. Instead, it should motivate them to understand viruses better so they can better educate their students. The first misconception about Ebola is that there is only one strain of Ebola that can cause EVD in humans when there are actually four (Item 4). The most likely reason for this misconception is that whenever Ebola was mentioned, it was just called “Ebola”, and not by the strain of Ebola that was causing the outbreak. This could have lead people to believe that there is only one strain that makes people sick, when there is actually four (Zaire, Sudan, Bundibugyo, & Tai Forest) that scientists have discovered. This could

cause a problem since each of the four viruses has a different mortality rate. Also, people know there are different strains of the flu because it is discussed every year, however, it seems like different strains of other viruses are almost never mentioned, which may cause people to believe there is only one strain of most viruses. The best way to mitigate this misconception is for the media to mention the strains with the viruses just like they do with major flu outbreaks like H5N1. The fact that students had a misconception about how many patients experience massive blood loss was not surprising (Item 6). What was surprising was the misconception that about 20% of patients experience massive blood loss. When the assessment was designed, the expected misconception was that all patients who die experience massive blood loss. This researcher is unsure why this was the misconception students had and should be further explored in the future. The best way to mitigate this misconception is also to mention that only half of patients experience massive blood loss in the media. The next misconception was on the average length of time for the incubation period, with most students choosing 2-10 days, which is in the correct range but not as long as the actual incubation time (Item 17). A possible reason for this misconception is that the incubation is 2-21 days but the average is 7-10 days, which may confuse the public on how long people are actually contagious. This is a dangerous misconception to have because people with this misconception can cause others to get infected causing the virus to spread even more. Therefore, it is crucial that teachers and the media work to address this misconception in the future to help mitigate the number of cases. The best way to address this misconception may be to just talk about the 2-21 day incubation period and not mention the average is 7-10 days to cause less confusion. This misconception may be due to the fact that some viruses do have an

incubation period from a few days to two weeks (Lessler, 2009). Also the most common viruses we are used to getting is the flu which has an incubation period of one to four days (CDC, 2009). About half of the students knew the mortality rate of the 2014/2015 Ebola outbreak was about 51%, and the other half were about evenly split over the distractors (Item 18). There are two main reasons students may have a misconception about the mortality rate of Ebola. The first is that the mortality rates of the different strains vary from 25-90% (WHO, 2014). The second reason is that the mortality rate initially fluctuated a little while data were being collected and cases were being validated. The best way to address this misconception is to not mention mortality rate until researchers are confident in the value or at least mention that it may fluctuate slightly as new cases are discovered and confirmed. Misconceptions on mortality rate can either cause undue panic if the mortality rate is overestimated, or cause people to not be as concerned as they should. If people are not as concerned as they should be, they may not follow all the transmission prevention methods, which would lead to disease spread. The last misconception students had was which viruses and bacteria had a lower survival rate than Ebola with students believing influenza and anthrax both had a higher survival rate (Item 24). Many studies have shown that people do not consider the flu to be deadly even though the annual death toll from the flu in the US is in the tens of thousands (Hollmeyer et al, 2009; Virseda et al, 2010; Leggat, Speare, & Aitken, 2009). People in the US should be much more concerned about the flu than they are; if they were more concerned about it, vaccination rates would increase. This would help decrease the number of flu deaths drastically. A reason students may believe that anthrax has a lower survival rate than Ebola is that in the US, anthrax is typically considered a weapon of mass destruction

after the Amerithrax attack (FBI) and not something that you can get from getting dirt in a wound. The best way to address these misconceptions is to simply compare Ebola to these viruses to give people a more accurate perspective on it.

Difference in Misconceptions between Students with and without a Strong Background in Science

It would be expected that students with a strong background in science would have fewer misconceptions about Ebola. The main reason is that students with a strong background in science will be better able to apply knowledge on other viruses to Ebola to eliminate incorrect answers or choose the correct answer. A double edged sword to this discussion is that numerous studies have shown that teachers with more science knowledge are more confident, and that ease of retrieval also increases knowledge (Appleton, 1995; Kelley & Lindsay, 1993; Gardner-Medwin, 1995; Harlen & Holroyd, 1997). This is a double edged sword because students with a strong science background will have more confidence in their answers, which means they are more likely be considered to have a misconception on a topic. Even with this bias, students with a strong science background had statistically significantly fewer misconceptions than students without. However, if science majors have misconceptions that they aquire from a non-scientific source but they still consider to be a scientific conception, it may be more difficult to correct than a non-science major with the same misconception.

This study raises the important question of how to make sure all students have correct understandings of viruses like Ebola since there is a difference in misconceptions between science and non-science majors. The first problem as stated earlier is that it may be more difficult to address science majors' misconceptions than non-science majors with

the same misconception. There have been some studies done on ways to address misconceptions. One study done with non-science majors used a folder activity where students had to do written homework that was turned in and the professor provided written feedback promptly to the students (Hein, 1999). The homework varied from explaining a problem or concept discussed in class or designing exam questions with explanations of their responses. By providing prompt feedback on students thought along with corrected answers, misconceptions can be quickly addressed. JiTT is also a very effective way to address misconceptions as shown in this study. One study found that while biology majors may share the same misconceptions as non-biology majors, biology majors were more methodical and organized in their reasoning (Coley & Tanner, 2014). Therefore, the best way to address science majors' misconceptions is with better facts and evidence than the "evidence" they based the misconception on because science students, and scientists in general, understand that nothing in science is proven. Stronger evidence for a different theory may come along that forces us to shift our conceptions on a subject. In fact, scientists are used to the field constantly changing as new discoveries are made and are used to having to change our concepts of things to fit the new discoveries. Also, science teachers have a huge influence on science majors (MacCurdy, 1956). Therefore, science teachers will need to be the ones to dispel these misconceptions that science majors have.

Since the logit averages for science and non-science majors were to the left of any item logits, the average number of students that had that misconception according to their CRI and score was calculated (Data not shown). There was a 20-30% difference between

science and non-science majors for all items indicating there was not four specific items that were different, but rather the misconceptions varied from student to student.

Just in Time Teaching

Just-in-Time Teaching can be used in any kind of class, large or small, undergraduate or graduate, major or non-major, and so on. JiTT allows professors to tailor the lesson to the students, which helps increase cognitive gains by determining students' prior knowledge, level of understanding, and misconceptions (Marris & Novak, 2004). JiTT not only significantly increased students' knowledge about Ebola with or without CRI integrated, but it also significantly reduced the average number of misconceptions students had by seven. This study showed that VirEMiA could be used effectively as the pre-class assignment that the instructor can then use to guide the discussion on Ebola.

Recommendations for University Health Education Programs

It is vital for students in health education programs to understand not just Ebola, but other viruses and bacteria that can cause epidemics and pandemics because they will be the ones teaching future students about them. If they have misconceptions about viruses, they will spread those misconceptions to their students. Therefore, professors of these courses should take full advantage of all the assessments that exist for identifying misconceptions on viruses. They should also take full advantage of JiTT to address these misconceptions. They should also teach their students how to read and understand scientific papers so they can find evidence to accept or refute a concept for themselves. Finally, they should teach students what sources are trustworthy for scientific information and why they should evaluate information from the media with skepticism.

Recommendations for Integrating Instruction on Viruses like Ebola into College Coursework

In this researcher's experience, viruses are a subject in science that is shied away from in this researcher's experience. This is a huge problem since viruses are a part of life and misconceptions about them can contribute to disease spread. Therefore, viruses need to be included in college coursework. Professors could use VirEMiA in the classroom for JiTT, when the subject is Ebola or hemorrhagic fevers with Ebola as the example or for any subject riddled with misconceptions that has a validated and reliable assessment for finding these misconceptions. Even if professors are not sufficiently confident in their knowledge of viruses to address misconceptions, they should at least teach students how to determine if a concept is a scientific concept or a misconception. They can accomplish this in the same way recommended to professors teaching health education programs.

Recommendations for Educating the Public

The CDC, WHO, and the media have an ethical responsibility to educate the public correctly and not create or proliferate misconceptions. The media are one of the offenders for spreading misconceptions because they have misconceptions themselves. Three studies found that most respondents indicated the radio, newspaper, friends, and television as their primary source of information about Dengue virus (Jones *et al.*, 2005; Priyadarsini *et al.*, 2014; Heng *et al.*, 1998). The media need to stop this and make sure that what they say is a scientific concept. Lately the CDC and WHO have become much better at using social media to address misconceptions people have. They have also started creating surveys like that presented here to study misconceptions people have and

address them using social media, like they did with misconceptions on antibiotic resistance (WHO, 2014). In the future, people at the CDC or WHO could give VirEMiA to random citizens to determine what misconceptions the public has. They could then tailor their mass media messages to address these misconceptions, mitigating unnecessary fear and panic citizens may have.

Future Revisions to VirEMiA

Another possible reason students had the misconception that only one strain of Ebola that can cause EVD in humans is that they do not know what a strain is. This is supported by the fact that high ability students had less confidence in their answer than low ability students since high ability students are more likely to know what a strain is. However to confirm this if the misconception is due to them not understanding what a strain is or if the misconception is that there is only one strain of Ebola, another item would be added to the beginning of the assessment asking "What is a strain?" with the following answer choices: a) "A subtype of a virus", b) "Another word for species used when talking about viruses", c) "A genetically engineered virus", and d) "A virus that is harmful to people", with the correct answer being "A". Item 6 did not misfit the Rasch model with or without confidence integrated. This suggests that the reason students underestimated the number of Ebola patients that hemorrhage instead of overestimating as expected was due to there not being a distractor with a percent above 50, answer choice a) "All patients, even those that live" will be changed to "About 70% of patients". Item 17 also did not misfit the Rasch model before or after confidence was integrated which suggests the reason students had a misconception may be that 2-10 days is a subset of the correct answer, 2-21 days. To determine if students actually have a misconception

about Ebola's incubation period or if the 2-10 day distractor confused students, answer choice a) "2-10 days" would be removed.

It should be obvious to avoid the bodily fluids of an infected dead person, which is why this item misfit the Rasch model before and after confidence was integrated. Even though this item is obvious and everyone should get it correct, it was kept in the assessment to make sure that the majority of people did get it correct. 19e "It is just a myth that Ebola is dangerous" could be removed since this is also an obvious answer to people in developed countries. However, if this assessment were to be used in Africa, this item would need to be included since they may have this misconception (CMSC, 2015; CRS, 2014; Shittu *et al.*, 2015). Item 20f could be removed from the assessment since it is "None of the Above" and no students selected it and it misfit the model when confidence was integrated. Item 22 "How long are people contagious with a virus" most likely misfit since we are taught from an early age that we are contagious when we are showing symptoms even though someone can be contagious even when they are not showing symptoms, due to the virus still being in their blood and secretions. For example, researchers have found Ebola can be passed on through semen months after a person recovered from the virus and stopped showing symptoms (CDC, 2014). To get this item to fit the Rasch model a) "As long as they are showing symptoms" would be removed. 23d "None of the above kills more people on average per year than Ebola" misfit the Rasch model when confidence was integrated and could be fixed by removing the answer choice or replacing it with another virus that does not kill more people on average per year than Ebola, such as smallpox.

IRB Approval

This research has IRB exempt approval through Wright State University SC# 6011.

REFERENCES

Alvarez, C. P., Lasala, F., Carrillo, J., Muniz, O., Corbi, A. L., & Delgado, R. (2002). C-type lectins DC-SIGN and L-SIGN mediate cellular entry by ebola virus in cis and in trans. *Journal of Virology, 76*(13), 6841-6844.

Ansari, A. A. (2014). Clinical features and pathobiology of ebolavirus infection. *Journal of Autoimmunity, 55*(0), 1-9. doi:http://dx.doi.org/10.1016/j.jaut.2014.09.001

Appleton, K. (1997). Student Teachers' Confidence to teach Science: Is More Science Knowledge Necessary to Improve Self-Confidence? *International Journal of Science Education, 17*(3), 357-369.

Arons, A. B. "Some Thoughts on Reasoning Capacities Implicitly Expected of College Students." In J. Lockhead and J. Clemens (eds.), Cognitive Process Instruction: Research on Teaching and Learning Skills (pp. 209–215). Philadelphia: Franklin Institute Press, 1979.

Basch, C. H., Basch, C. E., Ruggles, K. V., & Hammond, R. (2015). Disaster Medicine and Public Health Preparedness. *Disaster Medicine and Public Health Preparedness, 9*(5), 531-535.

Basler, C. F., Wang, X., Muhlberger, E., Volchkov, V., Paragas, J., Klenk, H. D., . . . Palese, P. (2000). The ebola virus VP35 protein functions as a type I IFN antagonist. *Proceedings of the National Academy of Sciences. United States of America, 97*(22), 12289-12294. doi:10.1073/pnas.220398297 [doi]

Bhattacharjee, Y. (2011). Panel Selects Most Dangerous Select Agents. *Science, 322*, 1491-1492.

Bond, T. G., & Fox, C. M. (2007). Fundamental measurement in the human sciences (2nd ed.). Mahwah, NJ: Lawrence Erlbaum.

Breckler, S., J. (2005). Psychology and the Frontier of Science. *Monitor on Psychology, 36*(8), 61.

Byrne, J., & Grace, M. (2010). Using a concept mapping tool with a photograph association technique (CoMPAT) to elicit children's ideas about microbial activity. *International Journal of Science Education, 32*(4), 479-500.

Catholic Relief Services (CRS), Focus 1000, Unicef. (2014). *Study on Public Knowledge, Attitudes, and Practices Relating to Ebola Virus Disease (EVD) Prevention and Medical Care in Sierra Leone.* Retrieved from http://newswire.crs.org/wp-content/uploads/2014/ 10/Ebola-Virus Disease-National-KAP-Study-Final-Report_-final.pdf

Centers for Disease Control and Prevention (CDC). (2015). *Cases of Ebola Virus Disease in Africa, 1976-2014*. Retrieved from http://www.cdc.gov/vhf/ebola/outbreaks/history/distribution-map.html

Centers for Disease Control and Prevention (CDC). (2009). *Clinical Signs and Symptoms of Influenza.* Retrieved from: http://www.cdc.gov/flu/professionals/acip/clinical.htm

Centers for Disease Control and Prevention (CDC). (2015). *CDC Ebola Guidance*. Retrieved from http://www.cdc.gov/vhf/ebola/pdf/ebola-guidance-travelers.pdf

Centers for Disease Control and Prevention (CDC). (2016). *Lifetime Risk of HIV Diagnosis.* Retrieved from: http://www.cdc.gov/nchhstp/newsroom/2016/croi-press-release-risk.html

Centers for Disease Control and Prevention (CDC). (2014). *Questions and Answers on Ebola*. Retrieved from: http://www.cdc.gov/vhf/ebola/outbreaks/2014-west-africa/qa.html.

Center for Media & Strategic Communication (CMSC). (2015). *Baseline Survey Report for Ebola Awareness in some Risk Groups in Yaounde.* Retrieved from http://www.cmsccameroon.org

Coley, J. D., Tanner, K. (2014). Relations between Intuitive Biological Thinking and Biological Misconceptions in Biology Majors and Nonmajors. *CBE Life Science Education, 14*(1).

Crouch, C. H., and Mazur, E. (2001). Peer Instruction: Ten Years of Experience and Results. *American Journal of Physics*, *69*, 970–977.

DiClemente, R. J., Zorn, J., Temoshok, L. (1986). Adolescents and AIDS: A Survey of Knowledge, Attitudes and Beliefs about AIDS in San Francisco. *American Journal of Public Health, 76*(12), 1443-1445.

Fauci, A. S. (2014). Ebola—underscoring the global disparities in health care resources. *New England Journal of Medicine*, *371*(12), 1084-1086.

Federal Bureau of Investigation (FBI). *Amerithrax or Anthrax Investigation*. Retrieved from: https://www.fbi.gov/about-us/history/famous-cases/anthrax-amerithrax

Feldmann, H., & Geisbert, T. W. (2011). Ebola haemorrhagic fever. *The Lancet, 377*(9768), 849-862.

Food and Drug Administration (FDA). (2015). *Anthrax.* Retrieved from: http://www.fda.gov/BiologicsBloodVaccines/Vaccines/ucm061751.htm

Formica, S. P., Easley, J. L., and Spraker, M. C. (2010). Transforming Common-Sense Beliefs into Newtonian Thinking through Just-in-Time Teaching. *Physics Education Research, 6*.

Galli, S., Chiesi, F., & Primi, C. (2008). The construction of a scale to measure mathematical ability in psychology students: An application of the Rasch Model. *TPM (Testing Psicometria Metodologia), 15*(1), 1–16.

Gardner-Medwin, A. R. (1995). Confidence Assessment in the Teaching of Basic Science. *Research in Learning Technology*, *3*(1), 80-85

Georges, A. J., Leroy, E. M., Renaut, A. A., Tevi Benissan, C., Nabias, R. J., Trinh Ngoc, M., . . . Georges-Courbot, M. C. (1999). Ebola Hemorrhagic Fever Outbreaks in Gabon, 1994-1997: Epidemiologic and Health Control Issues. *Journal of Infectious Disease, 179*, S65-S75.

Gortner, R. A. (1938). Viruses – Living or Non-Living? *Science, 87*(2267), 529-530.

Guenno, B. L., & Galabru, J. (1997). Ebola virus. *Bulletin de I'Institut Pasteur, 95*, 73-83.

Hake, R. R. (1998). Interactive-Engagement versus Traditional Methods: A Six-Thousand Student Survey of Mechanics Test Data for Introductory Physics Courses. *American Journal of Physics, 66*, 64–74.

Harlen, W. Holroyd, C. (1997). Primary Teachers' Understanding of Concepts of Science: Impact on Confidence and Teaching. *International Journal of Science Education, 19*(1), 93-105.

Hasan, S., Bagayoko, D., & Kelley, E. L. (1999). Misconceptions and the certainty of response index (CRI). *Physics Education, 34*(5), 294-299.

Hein, T. L. (1999). Using Writing to Confront Student Misconceptions in Physics. *European Journal of Physics, 20,* 137-141.

Henao-Restrepo, A. M., Longini, I. M., Egger, M., Dean, N. E., Edmunds, W. J., . . . Røttingen, J-A. (2015). Efficacy and Effectiveness of an rVSV-vectored Vaccine Expressing Ebola Surface Glycoprotein: Interim Results from the Guinea Ring Vaccination Cluster-Randomised Trial. *The Lancet,* Online. Retrieved from: http://www.thelancet.com/ journals/ lancet/article/PIIS0140-6736(15)61117-5/abstract

Heng, B. H., Goh, K. T., How, S. T., & Chua, L. T. (1998). Knowledge, attitude, belief and practice on dengue and Aedes mosquito. *Dengue in Singapore.* 167-183.

Hestenes, D., and Halloun, I. (1995). Interpreting the Force Concept Inventory: A Response to Huffman and Heller. *Physics Teacher, 33*, 502–506.

Heymann, D. L., Weisfeld, J. S., Webb, P. A., Johnson, K. M., Cairns, T., Berquist, H. (1978). Ebola Hemorrhagic Fever: Tandala, 1977-1978. *Journal of Infectious Disease, 142*, 372-376.

Hollmeyer, H., Hayden, F., Poland, G., & Buchholz, U. (2009). Influenza vaccination of health care workers in hospitals—A review of studies on attitudes and predictors. *Vaccine, 27*, 3935–3944.

Hummel, S. (2014). Ebola: Not an Effective Biological Weapon for Terrorists. *CTC Sentinel.*

Institute for Digital Research and Education (IDRE). (2015). What does Cronbach's alpha mean? Retrieved from: http://www.ats.ucla.edu/stat/spss/faq/alpha.html.

Johnson, K. M. (1978). Ebola Haemorrhagic Fever in Zaire, 1976. *Bulletin World Health Organization, 56*(2), 271-293.

Jones, M. G., & Rua, M. J. (2008). Conceptual representations of flu and microbial illness held by students, teachers, and medical professionals. *School Science and Mathematics, 108*(6), 263-278.

Jones, T. F., Larson, C., McCauley, T., Gottfried, K., & Schaffner, W. (2005). Public knowledge, attitudes and behaviors regarding West Nile virus. *Infectious Diseases in Clinical Practice, 13*(1), 2-4.

Kaye, D., Pollack, M. P. (2014). Mers vs. Sars: Compare and Contrast. Retrieved from: http://www.healio.com/infectious-disease/emerging-diseases/news/print/infectious-disease-news/%7B422866a7-0445-49b3-ac14-54b39bebbba6%7D/mers-vs-sars-compare-and-contrast

Kelley, C. M., Lindsay, D. S.c(1993). Remembering Mistaken for Knowing: Ease of Retrieval as a Basis for Confidence in Answers to General Knowledge Questions. *Journal of Memory and Language, 32*(1), 1-24.

Khalid, Tahsin. (2001). Pre-Service Teachers' Misconceptions Regarding Three Environmental Issues. *Canadian Journal of Environmental Education, 6*, 102-120.

Khan, A. S., Tshioko, F. K., Heymann, D. L., Le Guenno, B., Nabeth, P., Kerstiens, D. L., . . . Ksiazek, T. G. (1999). The Reemergence of Ebola Hemorrhagic Fever, Democratic Republic of the Congo, 1995. *Journal of Infectious Disease, 179*, S76-S86.

Koenig, K. L. (2012). Bioterrorism: Threat Analysis, Identification, Clinical Management. Retrieved from: https://www.youtube.com/watch?v=47_Jc1NkhNI

Leggat, P., Speare, R., & Aitken, P. (2009). Swine flu and travelers: An Australian perspective. *Journal of Travel Medicine, 16*(6), 373–376.

Leroy, E. M., Kumulungui, B., Pourrut, X., Rouquet, P., Hassanin, A., Yaba, P., . . . Swanepoel, R. (2005). Fruit bats as reservoirs of ebola virus. *Nature, 438*(7068), 575-576.

Lessler, J., Reich, N. G., Brokkmeyer, R., Perl, T. M., Nelson, K. E., Cummings, D. A. (2009). Incubation Periods of Acute Respiratory Viral Infections: A Systematic Review. *Lancet Infectious Disease, 9*(5), 291-300

MacCurdy, R. D. (1956). Characteristics and Backgrounds of Superior Science Students. *The School Review, 64*(2), 67-71.

Maron, D. F. (2014). Weaponized Ebola: Is It Really a Bioterror Threat? *Scientific American.*

Marris, K. A., Novak, G. (2004). Just-in-Time Teaching in Biology: Creating an Active Learner Classroom Using the Internet. *Cell Biology Education, 3*(1), 49-61.

Milliken, G. (2015). Are Viruses Alive? New Evidence Says Yes. *Popular Science.* Retrieved from: http://www.popsci.com/new-evidence-that-viruses-are-alive

Morvan, J. M., Deubel, V., Gounon, P., Nakouné, E., Barrière, P., Murri, S., . . . Gautier-Hion, A. (1999). Identification of ebola virus sequences present as RNA or DNA in organs of terrestrial small mammals of the central african republic. *Microbes and Infection, 1*(14), 1193-1201.

Muhlberger, E., Weik, M., Volchkov, V. E., Klenk, H. D., & Becker, S. (1999). Comparison of the transcription and replication strategies of marburg virus and ebola virus by using artificial replication systems. *Journal of Virology, 73*(3), 2333-2342.

Noda, T., Sagara, H., Suzuki, E., Takada, A., Kida, H., & Kawaoka, Y. (2002). Ebola virus VP40 drives the formation of virus-like filamentous particles along with GP. *Journal of Virology, 76*(10), 4855-4865.

Novak, G. M. (2011). Just-in-Time Teaching. *New Directions for Teaching and Learning, 2011*(128), 63-73

Olson, K. B. (1999). Aum Shinrikyo: Once and Future Threat? *Emerging Infectious Diseases, 5*(4).

Penn Medicine. *HIV Myths and Misconceptions.* Retrieved from: http://www.uphs.upenn.edu/pennactu/myths.shtml

Pourrut, X., Kumulungui, B., Wittmann, T., Moussavou, G., Délicat, A., Yaba, P., . . . Leroy, E. M. (2005). The Natural History of Ebola Virus in Africa. *Microbes and Infection, 7*(7), 1005-1014.

Preston, R. (1995). *The Hot Zone.* New York, NY: Anchor Books.

Priyadarsini, S. P., Nayeem, R. A., & Kannan, C. (2014). Study on Awareness and Prevention of Dengue Fever in a Selected Rural Area, Salem, Tamil Nadu-Descriptive Longitudinal Study. *International Journal of Health Sciences and Research (IJHSR), 4*(9), 14-20.

Reid, S. P., Leung, L. W., Hartman, A. L., Martinez, O., Shaw, M. L., Carbonnelle, C., . . . Basler, C. F. (2006). Ebola virus VP24 binds karyopherin alpha1 and blocks STAT1 nuclear accumulation. *Journal of Virology, 80*(11), 5156-5167. doi:80/11/5156 [pii]

Ramirez, J. E., Ramos, D. M., Clayton, L., Kanowitz, S., Moscicki, A-B. (1997). Genital Human Papillomavirus Infections: Knowledge, Perception of Risk, and Actual Risk in a Nonclinic Population of Young Women. *Journal of Women's Health, 6*(1), 113-121.

Romine, W. L., Barrow, L. H., & Folk, W. R. (2013). Exploring secondary students' knowledge and misconceptions about influenza: Development, validation, and implementation of a multiple-choice influenza knowledge scale. *International Journal of Science Education, 35*(11), 1874-1901.

Rumsey, D. (2011). *Statistics for Dummies* (2nd ed.). Retrieved from: http://www.dummies.com/how-to/content/how-sample-size-affects-standard-error.html

Sabourin, C. L. (2015). *The Path to Licensure: Ebola Vaccines* [PDF document]. Presented at the 25th Annual Society of Toxicology and ToxExpo

Saijo, M., Niikura, M., Ikegami, T., Kurane, I., Kurata, T., & Morikawa, S. (2006). Laboratory diagnostic systems for ebola and marburg hemorrhagic fevers developed with recombinant proteins. *Clinical and Vaccine Immunology : CVI, 13*(4), 444-451. doi:13/4/444 [pii]

Sanchez, A., Kiley, M. P., Holloway, B. P., & Auperin, D. D. (1993). Sequence analysis of the ebola virus genome: Organization, genetic elements, and comparison with the genome of marburg virus. *Virus Research, 29*(3), 215-240.

Shittu, R., Sanni, M., Odeigah, L., Akanbi, I., & AA, S. A. (2015). Awareness, Knowledge and Misconceptions about Ebola Virus Disease (EVD) in a Family Practice Setting in Nigeria, West Africa. *J Antivir Antiretrovir, 7*, 010-014.

Simonneaux, L. (2000). A study of pupils' conceptions and reasoning in connection with 'microbes', as a contribution to research in biotechnology education. *International Journal of Science Education, 22*(6), 619-644.

Stewart, S. (2014). Evaluating Ebola as a Biological Weapon. *Stratford Global Intelligence*. Retrieved from: https://mysu.susqu.edu/personal/rusek/news/Saved% 20Articles/Ebola %20as% 20a%20Biological%20Weapon.pdf

Tavakol, M., Dennick, R. (2011) Making Sense of Cronbach's Alpha. *International Journal of Medical Education,* 2, 53-55.

Uekawa, K. (2005). Explaining Rasch model in 3 minutes to a person who knows at least OLS regression. Retrieved from www.estat.us/sas/Rasch3minutes.doc.

Virseda, S., Restrepo, M., Arranz, E., Magan-Tapia, P., Fernandez-Ruiz, M., Gomez de la Camara, A., Aguado, J., & Lopez-Medrano, F. (2010). Seasonal and pandemic A (H1N1) 2009 influenza vaccination coverage and attitudes among health-care workers in a Spanish university hospital. *Vaccine, 28*, 4751–4757.

Villarreal, L. P. (2008). Are Viruses Alive? *Scientific American*. Retrieved from: http://www.scientificamerican.com/article/are-viruses-alive-2004/

Vincent, R. C., & Basil, M. D. (1997). College students' news gratifications, media use, and current events knowledge. *Journal of Broadcasting & Electronic Media, 41*(3), 380-392.

White, J. M., & Schornberg, K. L. (2012). A new player in the puzzle of filovirus entry. *Nature Reviews Microbiology, 10*(5), 317-322.

World Health Organization (WHO). (2014). *Ebola Virus Disease Fact Sheet Nº103.* Retrieved from: http://www.who.int/mediacentre/factsheets/fs103/en/

World Health Organization (WHO). (2011). *Frequently Asked Questions: H5N1 Influenza.* Retrieved from: http://www.who.int/influenza/human_animal_interface /avian_influenza/h5n1_research/faqs/en/

World Health Organization (WHO). (2013). *Number of Deaths Due to HIV/AIDS.* Retrieved from: http://www.who.int/gho/hiv/epidemic_status/deaths_text/en/

World Health Organization (WHO). (2012). *Number of Malaria Deaths.* Retrieved from: http://www.who.int/gho/malaria/epidemic/deaths/en/

World Health Organization (WHO). (2010). *Infection Control for Viral Haemorrhagic Fevers in the African Health Care Settings.* Retrieved from: http://apps.who.int/iris/handle/10665/65012.

World Health Organization (WHO). (2015). *WHO multi-country survey reveals widespread public misunderstanding about antibiotic resistance.* Retrieved from: http://www.who.int/mediacentre/news/releases/2015/antibiotic-resistance/en/

Williams, B. (2011). Cohen's d and Effective Size. [Weblog]. Retrieved from: http://mandeblog.blogspot.com/2011/05/cohens-d-and-effect-size.html

Wollack, J. A. Item Analysis. Retrieved from: http://www.son.wisc.edu/net/wistrec/net/ItemAnalysisText.htm

Wong, G., Kobinger, G. P., & Qiu, X. (2014). Characterization of host immune responses in ebola virus infections. *Expert Review of Clinical Immunology, 10*(6), 781-790.

Wright, B. D. & Stone, M. H. (1979). *Best Test Design*. Chicago: MESA Press.

Yang, Z., Duckers, H. J., Sullivan, N. J., Sanchez, A., Nabel, E. G., & Nabel, G. J. (2000). Identification of the ebola virus glycoprotein as the main viral determinant of vascular cell cytotoxicity and injury. *Nature Medicine, 6*(8), 886-889.

APPENDIX A

Pilot VirEMiA with Answers and Categories

Virus and Ebola Misconceptions Assessment (VirEMiA)

Sex: M/F Ethnicity: _____ Major: _____

Please select the answer choice you think is the best answer to the question. For some questions, more than one answer may be correct. Following each multiple choice question, there will be a follow-up question that will require a short written response. For each answer selected, click one of the confidence level choices based on how confident you feel the answer you selected is correct:

1) What causes Ebola disease?
   a) Bacteria
   b) Prokaryote
   c) Virus
   d) Eukaryote
   e) Bacteriophage
   f) Other _____

CRI:
   a) Complete Guess
   b) Uncertain
   c) Certain
   d) Very confident

Briefly explain why you chose that answer.

2) _____ are produced from the assembly of pre-formed components, don't grow or undergo division, and lack the genetic information necessary for energy generation or protein synthesis.
   a) Bacteria
   b) Prokaryote
   c) Virus
   d) Eukaryote
   e) Bacteriophage
   f) Other _____

CRI:
   a) Complete Guess
   b) Uncertain
   c) Certain
   d) Very confident

Briefly explain why you chose that answer.

3) _____ are living single celled organisms that contain no nucleus or membrane bound organelles, typically have circular DNA, and can be beneficial or harmful to people.

a) Bacteria
b) Prokaryote
c) Virus
d) Eukaryote
e) Bacteriophage
f) Other _____

CRI:
a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

Briefly explain why you chose that answer.

4) Is a virus alive?
a) No, it is never alive
b) Yes, it is alive
c) It is alive inside a cell but non-living outside a cell
d) It is alive outside a cell but non-living inside a cell
e) Other

CRI:
a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

Briefly explain why you chose that answer.

5) How many strains of Ebola are there?
a) 1
b) 2
c) 3
d) 4
e) 5

CRI:
a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

What is/are the name(s) of the strain(s)?

6) Which of the following is/are symptom(s) of Ebola? You may choose any or all of the answers.
a) Fever
b) Headache
c) Diarrhea
d) Bleeding
e) Cough

CRI:

a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

If you know any other symptoms of Ebola, please list them here.

7) How many Ebola patients bleed out?
   a) All patients, even those that live
   b) All patients that die
   c) About 90% of patients
   d) Less than half of the patients
   e) None, this is just a myth

CRI:

a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

Briefly explain why you chose that answer.

8) Which of the following is a way to tell if someone is infected with Ebola? You may choose any or all of the answers.
   a) By looking at them
   b) Testing their blood
   c) Autopsy
   d) Quarantine and monitor
   e) **Test for antibodies**
   f) All are ways to tell if someone is infected with Ebola.

CRI:

a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

Briefly explain why you chose that answer.

9) At this time, is there a medically proven and FDA approved treatment that neutralizes Ebola?
   a) Yes, there is a vaccine
   b) Yes, there are small molecule drug therapies
   c) Yes there are antibiotics
   d) No, there are no FDA approved treatments, but there are a few treatments undergoing evaluation
   e) No, there are no FDA approved treatments or treatments undergoing evaluation

CRI:

a) Complete Guess
b) Uncertain

c) Certain
d) Very confident

Please list any vaccines or treatments you have heard of and if possible, briefly describe what you know about how they work. If you have heard of a vaccine or treatment but don't know how it works, please still list it.

10) Which of the following is a means of preventing the spread of Ebola? You may choose any or all of the answers.
    a) Wearing surgical masks
    b) Avoiding contact with infected dead bodies
    c) Avoiding bodily fluids of an infected person
    d) Quarantining people who are suspected of being infected
    e) **Avoiding contact with infected host animals**

CRI:
    a) Complete Guess
    b) Uncertain
    c) Certain
    d) Very confident

List any other means of preventing the spread of Ebola.

11) Which of the following is/are a confirmed way Ebola is transmitted? You may choose any or all of the answers.
    a) Through the air
    b) From a mosquito bite
    c) Through casual contact like shaking hands with someone who is infected
    d) Through blood, secretions, and other bodily fluids
    e) Other _____

CRI:
    a) Complete Guess
    b) Uncertain
    c) Certain
    d) Very confident

Briefly explain why you chose that answer.

12) What is the average length of time between exposure to Ebola and when symptoms first appear (incubation period)?
    a) 2-10 days
    b) 1 month
    c) 6 months
    d) 1 year
    e) 2-21 days

CRI:
    a) Complete Guess
    b) Uncertain
    c) Certain
    d) Very confident

Based on your answer, how long would you recommend someone suspected of having Ebola be quarantined and why?

13) What is the mortality rate of the 2014/2015 Ebola outbreak?
    a) 100%
    b) 51%
    c) 87%
    d) 74%
    e) 92%

CRI:
    a) Complete Guess
    b) Uncertain
    c) Certain
    d) Very confident

Briefly explain why you chose that answer.

14) Why is Ebola so dangerous? You may choose any or all of the answers.
    a) It disables the immune system
    b) There is no treatment or cure
    c) The only way to tell if someone has it is to quarantine them and see if they hemorrhage, and if they do, it is too late to save them
    d) It has a high case/fatality rate
    e) Other _____

CRI:
    a) Complete Guess
    b) Uncertain
    c) Certain
    d) Very confident

Briefly explain why you chose that answer.

15) Which of the following is a suspected host or reservoir for Ebola? You may choose any or all of the answers.
    a) Humans
    b) Bats
    c) Monkeys
    d) Apes
    e) Mosquitos
    f) Other _____

CRI:
    a) Complete Guess
    b) Uncertain
    c) Certain
    d) Very confident

Briefly explain why you chose that answer.

16) Who is at risk of contracting Ebola? You may choose any or all of the answers.

a) People who have had direct contact with blood or bodily fluids from someone with symptoms through splashes to nose, eye, mouth, break in the skin, or a needlestick
b) People who care for someone showing Ebola symptoms, but have not taken precautions to prevent transmission
c) Anyone who comes into contact with a person or food from an Africa
d) Other _____

CRI:
a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

Briefly explain why you chose that answer.

17) How long are people contagious with a virus?
a) As long as they are showing symptoms
b) As long as their blood and secretions contain the virus
c) The rest of their life
d) Only when they have a fever
e) Up to two weeks after they start showing symptoms
f) Other _____

CRI:
a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

Briefly explain why you chose that answer.

18) Which kills more people on average per year than Ebola? You may choose any or all of the answers.
a) Influenza (all strains together)
b) HIV/AIDS
c) Malaria
d) Dengue
e) Rabies

CRI:
a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

Briefly explain why you chose that answer.

19) Which has a higher case/fatality rate than Ebola's 2014/2015 case/fatality rate? You may choose any, all, or none of the answers.
a) Influenza (H5N1)
b) MERS/SARS

c) Smallpox
d) Bubonic plague
e) Rabies

CRI:
a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

Briefly explain why you chose that answer.

20) What are the chances of the average US citizen getting infected with Ebola?
a) Very High (80-100%)
b) High (50-79%)
c) Low (20-49%)
d) Very Low (5-19%)
e) Almost zero (0-4.9%)

CRI:
a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

Briefly explain why you chose that answer.

21) Is there anything else you know about Ebola that wasn't covered in the above questions?

APPENDIX B

Final Version of VirEMiA with Correct Answer Choices

Virus and Ebola Misconceptions Assessment (VirEMiA)

Sex: M/F Ethnicity: _____ Major: _____

Please select the answer choice you think is the best answer to the question. For some questions, more than one answer may be correct. For each answer selected, click one of the confidence level choices based on how confident you feel the answer you selected is correct:

1) What causes Ebola disease?
   a) Bacteria
   b) Prokaryote
   c) Virus
   d) Eukaryote
   e) Bacteriophage

CRI:
   a) Complete Guess
   b) Uncertain
   c) Certain
   d) Very confident

2) _____ are produced from the assembly of pre-formed components, don't grow or undergo division, and lack the genetic information necessary for energy generation or protein synthesis.
   a) Bacteria
   b) Prokaryote
   c) Virus
   d) Eukaryote

CRI:
   a) Complete Guess
   b) Uncertain
   c) Certain
   d) Very confident

3) _____ are living single celled organisms that contain no nucleus or membrane bound organelles, typically have circular DNA, and can be beneficial or harmful to people.
   a) Bacteria
   b) Prokaryote
   c) Virus
   d) Eukaryote

CRI:
   a) Complete Guess
   b) Uncertain
   c) Certain

d) Very confident

4) How many strains of Ebola have currently been identified?
   a) There is only one strain of Ebola
   b) There are about five strains of Ebola, all of which can cause Ebola disease in people
   c) There are about five strains of Ebola, most of which can cause Ebola disease in people
   d) There are about five strains of Ebola, one of which can cause Ebola disease in people

CRI:
   a) Complete Guess
   b) Uncertain
   c) Certain
   d) Very confident

5) Which of the following is/are symptom(s) of Ebola? You may choose any or all of the answers.
   a) Fever
   b) Headache
   c) Diarrhea
   d) Bleeding
   e) Cough

CRI:
   a) Complete Guess
   b) Uncertain
   c) Certain
   d) Very confident

6) How many Ebola patients experience massive blood loss?
   a) All patients, even those that live
   b) All patients that die
   c) About 50% of patients
   d) About 20% of patients
   e) None, this is just a myth

CRI:
   a) Complete Guess
   b) Uncertain
   c) Certain
   d) Very confident

7) You can tell if someone is infected with Ebola by looking at them.
   a) True
   b) False

CRI:
   a) Complete Guess
   b) Uncertain
   c) Certain
   d) Very confident

8) You can tell if someone is infected with Ebola by testing their blood.

a) True
b) False

CRI:
a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

9) You can tell if someone was infected with Ebola by performing an autopsy.
a) True
b) False

CRI:
a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

10) You can tell if someone has been infected with Ebola by testing for antibodies.
a) True
b) False

CRI:
a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

11) At this time, is there a medically proven and FDA approved treatment that neutralizes Ebola?
a) Yes, there is a vaccine
b) Yes, there are small molecule drug therapies
c) Yes there are antibiotics
d) No, there are no FDA approved treatments, but there are a few treatments undergoing evaluation
e) No, there are no FDA approved treatments or treatments undergoing evaluation

CRI:
a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

12) Which of the following is a means of preventing the spread of Ebola? You may choose any or all of the answers.
a) Wearing surgical masks
b) Avoiding contact with infected dead bodies
c) Avoiding bodily fluids of an infected person
d) Quarantining people who are suspected of being infected
e) **Avoiding contact with infected host animals**
f) **Washing Hands**

CRI:
a) Complete Guess

b) Uncertain
c) Certain
d) Very confident

13) Ebola is confirmed to be transmitted through the air.
a) True
b) False

CRI:
a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

14) Ebola is confirmed to be transmitted from a mosquito bite.
a) True
b) False

CRI:
a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

15) Ebola is confirmed to be transmitted through casual contact like shaking hands with someone who is infected.
a) True
b) False

CRI:
a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

16) Ebola is confirmed to be transmitted through blood, secretions, and other bodily fluids.
a) True
b) False

CRI:
a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

17) What is the average length of time between exposure to Ebola and when symptoms first appear (incubation period)?
a) 2-10 days
b) 1 month
c) 6 months
d) 12-48 hours
e) 2-21 days

CRI:
a) Complete Guess

b) Uncertain
c) Certain
d) Very confident

18) What is the mortality rate of the 2014/2015 Ebola outbreak?
a) 94%
b) 73%
c) 51%
d) 21%
e) 2%

CRI:
a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

19) Why is Ebola so dangerous? You may choose any or all of the answers.
a) It causes cell death, shock, and multi-organ failure
b) There is no treatment or cure
c) The only way to tell if someone has it is to quarantine them and see if they hemorrhage, and if they do, it is too late to save them
d) It has a low survival rate (for example if 100 people get an illness and only 10 survive)
e) It is just a myth that Ebola is dangerous

CRI:
a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

20) Which of the following are suspected of being able to infect humans with Ebola? You may choose any or all of the answers.
a) Humans
b) Bats
c) Monkeys
d) Apes
e) Mosquitos
f) None of the above

CRI:
a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

21) Who has a high risk of contracting Ebola? You may choose any or all of the answers.
a) People who have had direct contact with blood or bodily fluids from someone with symptoms through splashes to nose, eye, mouth, break in the skin, or a needlestick
b) People who care for someone showing Ebola symptoms, but have not taken precautions to prevent transmission

c) Anyone who comes into contact with a person or food from an Africa

CRI:

a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

22) How long are people contagious with a virus?

a) As long as they are showing symptoms
b) As long as their blood and secretions contain the virus
c) The rest of their life
d) Only when they have a fever
e) Up to two weeks after they start showing symptoms

CRI:

a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

23) Which kills more people on average per year than Ebola? You may choose any or all of the answers.

a) Influenza (all strains together)
b) HIV/AIDS
c) Malaria
d) None of the above

CRI:

a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

24) Which has a lower survival rate than Ebola's 2014/2015 survival rate (for example if 100 people get an illness and only 10 survive)? You may choose any, all, or none of the answers.

a) Influenza (H5N1)
b) MERS/SARS
c) Anthrax
d) HIV/AIDS
e) None of the above

CRI:

a) Complete Guess
b) Uncertain
c) Certain
d) Very confident

25) What are the chances of the average US citizen getting infected with Ebola?

a) Very High (80-100%)
b) High (50-79%)
c) Low (20-49%)
d) Very Low (5-19%)

e) Almost zero (0-4.9%)

CRI:

a) Complete Guess
b) Uncertain
c) Certain
d) Very confident