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Can Public Health Workforce Competency and Capacity be built through an Agent-based Online, Personalized Intelligent Tutoring System?

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ABSTRACT: The COVID-19 pandemic hit the United States in 2020 resulting in a public health caseload surge precipitating deployment of military and federal medical units, states issuing emergency orders to engage retired medical professionals, and novice or inadequately trained healthcare workers thrust into service to meet the pressing need. The novelty and scope of the pandemic exposed a gap in the competency and the surge capacity of the public health workforce to address the societal needs during the pandemic. This research investigated the capability of an agent-based, online personalized (AOP) intelligent tutoring system (ITS) that adaptively uses aptitude treatment interaction (ATI) to deliver public health workforce training in a prescribed health regime and assure their competency. This research also considers the ability of such an AOP ITS to support rapidly surging capacity of the public workforce to scale to meet healthcare demands while remaining accessible and flexible enough to adapt to changing healthcare guidance. Findings indicate such a system increases participant performance while providing a high level of acceptance, ease of use by users, and competency assurance. However, discussion of our findings indicates limited potential for an AOP ITS using the current ATI paradigm to make a major contribution to adding public health workforce surge capacity unless workforce members are directed to utilize it and technology barriers in the current public health IT infrastructure are overcome.

Keywords: Agent, Intelligent tutoring system, Public health, Surge capacity, Competencies

1. Introduction

In late December 2019, COVID-19 virus struck Wuhan, China (CDC, 2020). In February 2020, the U.S. Centers for Disease Control and Prevention (CDC) indicated COVID-19 was not “spreading in the U.S.” (Jernigan, 2020) but by mid-March full on community mitigation phase was initiated (Schuchat, 2020). Epidemiology and surveillance skills, which includes conducting contact investigations and tracing, were needed to protect the society but were deficient since 2000 (Hilliard & Boulton, 2012; Lederberg, 2000). To meet the shortfall, the U.S. deployed Medical Reserve Corp and military and federal medical units, states allowed retired personnel to come back to work, and New York City (NYC) transferred to its public health system nearly 40 experienced contact tracers to lead and supervise 1,000 newly hired contact tracers (State of Florida, 2020; Office of the Mayor, 2020; HHS, 2020). Similar actions happened all over the country (Simmons-Duffin, 2020). Just in time training attempted to fill the gap in knowledge by providing lengthy online documents or providing hands-on experience in a “baptism by fire” strategy (Bauchner & Sharfstein, 2020; HHS, 2020). Since spreading into a full-fledged pandemic across the world, at the time of this writing, COVID-19 has infected more than 17 million people and killed more than 700,000 (JHU, 2020)

Rapid scale up of the public health workforce capacity is critical to prevent, detect, or mitigate an outbreak or pandemic but only if the workforce is competent in their knowledge, skills, abilities (KSA) (ASTHO, 2013; Tao, Evashwick, Grivna, & Harrison, 2018). Underfunding, dependency on categorical funding systems, and the decentralized fragmentation of the United States public health system challenges local and/or state governments to maintain appropriate competency especially in epidemiology (Leider, Coronado, Beck, & Harper, 2018; Soffen & Lu, 2017; Wadman, 2012; Partners, 2018). Budgets allocated for workforce training and development are also volatile. Decreasing by 57% in 2009 (APHA, 2011) and after reversing during restorative Affordable Care Act (ACA) funding have since suffered significant cuts up to 80% (Soffen & Lu, 2017; Wadman, 2012; Yeager, 2018).

1.1. A perspective on training and intelligent tutoring systems (ITS)

Educational programs and information disseminated by the CDC attempt to address public health workforce competency and capacity shortfalls (HHS, 2019). The gold standard for competency is on-the-job pairing of trainees with a seasoned epidemiologist in the field such as the Field Epidemiology Training Program (FETP) and the Epidemic Intelligence Service (EIS) program, which has been successfully implemented in 80 countries and has trained over 18,000 graduates since 1980 (CDC, 2020). On-the-job professional development is difficult (Beck, Boulton, & Coronado, 2014) and loss of talent to competing employers undermines local capacity for expert-to-novice mentorship and tutoring programs (Leider et al., 2018). Educational programs often prioritize licensed medical, dental, and nursing staff missing other licensed and non-licensed staff (Tao et al., 2018). As a result, the Department of Health and Human Services (HHS) estimates that only 20% of public health professionals have the KSA's to be effective (Beck et al., 2014; Hilliard & Boulton, 2012).

Face-to-face, on-the-job training as well as learning from peers within discussion groups competes with online learning approaches (Benta, Bologa, Dzitac, & Dzitac, 2015; Hilliard & Boulton, 2012; Kaur, 2013). On site face-to-face training is not efficient nor cost effective for large, geographically distributed populations with diverse student needs nor even practical in a short time frame due to non-availability of experts to train the less experienced when they are in the midst of addressing a pandemic (HHS, 2020; Sottilare & Proctor, 2012).

Synchronous online learning modalities with live instructors, if available, may be accomplished through distance media such as Zoom, WebEx, etcetera (Kaur, 2013). Asynchronous online learning modalities span independent internet searches of textual materials to online videos, tutorials, and intelligent tutoring systems (ITS) (Kaur, 2013). Proprietary online adaptive ITS systems such as those by educational publisher McGraw Hill and Pearson report antidotal success rates in formal educational institutions (McGraw-Hill, 2020; Pearson Higher Education, 2020). For the public health workforce, it was not until April 2020 that a series of asynchronous online teaching and learning approaches in contact investigations and tracing were introduced by CDC and its partners to respond to the COVID-19 pandemic (CDC, 2020). Learner engagement and competency were not accessed by that online training.

Fischetti & Gisolfi (1990) identified ITS as a computerized system that uses artificial intelligence (AI) to tutor a topic. ITS mimics student teacher interaction by modeling the state of a student learner to provide individual instruction (Ma, Adesope, Nesbit, & Liu, 2014). An ITS requires a knowledgeable domain expert for quality content, but once developed, online ITS can be accessed by many learners (Fischetti & Gisolfi, 1990) achieving greater cost effectiveness than traditional methods through greater scale and reuse (Gurunath, Ravi, & Srivatsa, 2012; Ruiz, Mintzer, & Leipzig, 2006). Online ITS enable any time, any location access that is not limited by classroom capacity (Gurunath et al., 2012). ITS learning management systems allow tracking and monitoring of a learner's KSA's while delivering more standardized course content (Ruiz et al., 2006).

Recognized as effective for many (Ramayah, Ahmad, & Tan, 2012; Yiu & Saner, 2005), newer ITS aim to achieve even better adaption and outcomes by employing agent technology (VanLehn, 2011). Commercial agent technology such as Cortana, Siri, Alexa, and Google Assistant leverage the Internet, vocally respond to questions, and provide information as "smart assistants," though do not currently tutor professional subject matter (Martindale, 2020). To be successful tutors, ITS agents must possess levels of autonomy, responsiveness, reactiveness or adaptability, pro-activeness, and social ability (Wooldridge & Jennings, 1995).

Emerging instructional agent-based, online personalized (AOP) ITS are flexible and adaptive on specialized content and contextually sensitive as a personal human tutor might through aptitude treatment interaction (ATI) (Stoilescu, 2008). ATI adapts learning strategies to specific student characteristics (e.g., prior knowledge, aptitude) in combination with 4 adaptive system modules (domain, learner, pedagogical and tutor-user interface) to provide appropriate feedback and instruction to remediate learning deficiencies through the tutor-user interface presented to the learner (Nguyen & Do, 2008; Sottilare, 2018). Real-time data analysis assesses performance, motivation, engagement, and learning (Fischetti & Gisolfi, 1990; Sottilare, 2018). Advanced ATI's address context and importance of student mood (Sottilare & Proctor, 2012), understanding complex issues and improving decision making (Wolfe et al., 2015), improving motivation (Sottilare, Graesser, Hu, & Goldberg, 2014), and improving training efficiency and flexibility (Oxman & Wong, 2014). Additionally, ITS have grown to span numerous specialized fields including mathematics, physics, and software programming, but not public health (Sottilare, 2018).

1.2. A perspective on usability and usefulness

Clearly a prospective public health trainee will be less inclined to voluntarily use an ITS unless it is perceived as usable and useful.

The Technology Acceptance Model (TAM) (Davis, 1989) mediates constructs of perceived usefulness (PU) - the degree to which a person believes that the use of an application or system will improve their job performance - and perceived ease of use (PEOU) - belief that the use of an application or system would be free of effort. PU and PEOU influence attitude toward use (ATT) and intention to use (IU) which indicates the level of acceptance of the technology (Gefen, Straub, & Boudreau, 2000; Turner, Kitchenham, Brereton, Charters, & Budgen, 2010). TAM is widely used in industries outside healthcare and accounts for 30-40% of IT acceptance assessments (Holden & Karsh, 2008; Legris, Ingham, & Collerette, 2003).

1.3. Competency of public health professional outbreak training

Public health professional competency may be measured in terms of knowledge of and compliance with a prescribed health regime. As an example, a health regime for members of a society combating the COVID-19 pathogen includes knowing to and complying with regular washing of hands with soap for 20 seconds and wearing a facial mask when in a group (CDC, 2020). The U.S. Public Health Service, as early as the 1950's, recognized with the Health Belief Model (HBM) that perception and belief of individuals, even professionals, often challenge compliance with health regimes (Rosenstock, 1974; Champion & Skinner, 2008; Rosenstock, Strecher, & Becker, 1988). HBM hypothesizes that compliance with a prescribed health regime decomposes into four Cues to Action (CA) constructs: perceived susceptibility (PS) to the health threat, perceived severity/seriousness (PSV) of the health threat, perceived benefits (PB) to taking the prescribed action, and perceived barriers/threats (PT). These constructs are combined with the motivation (M) of an individual to undertake the behavior (Utwente, 2017; Rosenstock et al., 1988). As currently seen in the COVID-19 pandemic, varying levels of knowledge and compliance to a prescribed health regime by individuals in the society is reflected in varying influences of these constructs (Clark, Davila, Regis, & Kraus, 2020; Van Bavel et al., 2020). Within the tutor, the prescribed health regime are protocols to manage measles and varicella pathogen. In our study, we are measuring the prescribed health regime as the actual use of an ITS.

In the U.S., the framework most frequently utilized to measure public health professional competency in administering a prescribed health regime is "The Core Competencies for Public Health Professionals." This framework contains 8 domains (PHF, 2014; Tao et al., 2018): Analytical/Assessment Skills, Policy Development/Program Planning Skills, Communication Skills, Cultural Competency Skills, Community Dimension of Practice Skills, Public Health Science Skills, Financial Planning and Management Skills, and Leadership and Systems Thinking Skills (PHF, 2014). Our tutor addresses KSA's in 4 of these domains.

2. Research design and methods

First, this research focuses on training and competency assurance of epidemiology and surveillance skills for public health professionals in administering protocols, procedures and processes for selected outbreak pathogens using an AOP ITS with ATI. Secondly, this research discusses the potential of an AOP ITS with ATI might have toward supporting surging up the epidemiology and surveillance skill capacity of the public health professional workforce needed by a society during an outbreak or pandemic. Thirdly, we utilize two theoretical frameworks (TAM & HBM) to understand perception for actual use of an AOP ITS with ATI by public health professionals.

The study involved an ITS that may address protocols, procedures and processes for COVID-19 or any other pathogen outbreak or pandemic, but for the purpose of this research the ITS addressed measles and varicella pathogens. Specifically, the ITS contained 8 learning concepts for each pathogen (16 total) but the study focused on 4. The concepts include epidemiological information for case and outbreak management. The ITS content is adapted from the Florida Department of Health's Epidemiology and Rash Illness Outbreak Tactics (EPI-RIOT): Combining Epidemiologic Practice with the Field Operations course (FBOE, 2009) and heavily supplemented by information from the CDC. The ITS was built using the Generalized Intelligent Framework for Tutoring (GIFT) platform developed by the Army Research Laboratory (ARL) (Sottilare, 2018).

The research involved survey and testing within a cross-sectional experimental study design engaging invited national, state, and local public health professionals. A pilot validated the ITS, testing, and survey instruments. User feedback from the pilot was used to refine or modify the ITS, the testing scenario, and the survey instruments. The modified course was then evaluated by 3 subject matter experts prior to study deployment.

The tutor course flow can be categorized into 4 sections. Section 1 is administrative and includes a 2-minute course navigation video, informed consent, course expectations, course objectives, 13 question learner attributes survey and a 10-question pre-test assessment with structured review. The structured review is one strategy used to provide feedback for learning. Section 2 contains the adaptive course flow modules for measles and varicella. This section contains the rule content files, example content files and check on learning phases used to assess and remediate learners. In the rule content, all learners are presented with a 9-minute measles overview video and 13-minute varicella overview video prior to the learning phase assessments of each topic. If competence is demonstrated within the learning phase, the learner is moved to the next section. If competence is not achieved, remediation strategies are provided using the example content files based on the learner's input. The example content files are a myriad of PowerPoint presentations, videos, websites, and PDF files. Section 3 contains the knowledge application scenario and a 10-question posttest assessment with a structured review. Section 4 is the research framework surveys which contain 3 questions on platform preferences, 22 questions for TAM and 34 questions for HBM.

The data collection tools are a combination of self-report and objective assessments in free text and multiple-choice formats. These survey tools are used to measure prior knowledge, knowledge acquisition and application, and learner attributes such as grit, motivation, and confidence. Learner remediation can take more time than anticipated by a learner as fundamental concepts may be known but not mastered requiring additional time for course completion. Grit (resilience or perseverance when faced with obstacles) was assessed by confidence in completing the entire course, confidence with the content, and willingness to learn on the ITS. Motivation (the reason for the learner's action) was assessed by asking participants about confidence in completing the entire course, willingness to learn on the ITS, and confidence in returning to the platform for a refresher course (Sottilare et al., 2014). Perception responses were based on TAM developed by Davis (1989) and validated by Davis, Bagozzi and Warshaw (1989) and HBM developed by the Public Health Service (1974) and validated by Champion (1984). Additional data collection methods for each hypothesis is described below.

Informed consent was sought for each phase in compliance with IRB guidance (UCF IRB SBE-18-14393). For both phases, the GIFT platform allows for respondent anonymity.

Our study consists of five hypotheses under test.
- Hypothesis A: Preference for obtaining knowledge
- Hypothesis B: Knowledge acquisition and application
- Hypothesis C: Technology Acceptance Model concepts
- Hypothesis D: Health Belief Model concepts
- Hypothesis E: AOP ITS using ATI attract learners to study on a voluntary basis

Hypothesis A. Our first research question is, "Do public health professionals' prefer an ITS platform, internet search, mentor or discussion group training modality?". The null hypothesis is that public health professionals are ambivalent about training modality. For learner perceptions on the ITS, the 3-question comparative analysis survey used Yes and No responses. The data collection for Hypothesis A is contained within a survey in section 4 of the tutor course flow.

Hypothesis B. Our second research question is: "Does an AOP ITS that uses ATI improve a public health professionals knowledge level and application of knowledge in an outbreak scenario?" The two-part null hypothesis is that the AOP ITS with ATI will not demonstrate participants improved post-assessment performance level over pre-assessment performance level or competency in applying knowledge in an outbreak scenario assessment.

Learner's knowledge improvement was assessed by survey evaluation of pre (given at the beginning of the course) and post (given at the end of the ITS instruction) performance. Prior knowledge focused on knowledge and experience with the health regime for a febrile rash illness and packaging and shipping clinical specimens. The Brenner's Novice to Expert model was used in the learner attribute survey to understand respondent's level of expertise. The model is composed of domains that differentiates theoretical knowledge from practical knowledge for clinical practice competencies. Brenner's clinical competency scale includes: (1) Novice = Minimal or only textbook knowledge; (2) Beginner = Some working knowledge; (3) Competent = Good background knowledge and area of practice; (4) Proficient = Depth of understanding of discipline and area of practice; (5) Expert = Comprehensive and authoritative knowledge (Kak, Burkhalter, & Cooper, 2001).

Knowledge application (competency) was evaluated in the ITS with an assessment requiring the learner to apply knowledge obtained to a scenario. It is also applied at the conclusion of each learning module wherein, a 4-question assessment is presented addressing the 4 learning concepts. Performance on these assessments adapts the tutor to move forward with the course if the learner demonstrates mastery of the concepts. If mastery is not obtained, the ITS re-formulates content delivery or medium and the learner is remediated until the criteria is met. Data collection for Hypothesis B is contained within the survey and assessment tools in sections 1, 2, and 3 of the tutor course flow.

Hypothesis C. Our third research question is, "Does an AOP ITS that uses ATI promote senses of useful, easy to use, positive attitude, and intention to use in public health professional users?" The null hypotheses are that public health professionals will be ambivalent about the usefulness (PU), ease of use (PEOU), attitude (ATT), or intent to use (IU) an AOP ITS with ATI. Learner's perception of the ITS was recorded for technology acceptance using a Likert 7-point scale (Table 5). Data collection for Hypothesis C is contained within the survey tools in section 4 of the tutor course flow.

Hypothesis D. Our fourth research question is, "Does content in an AOP ITS that uses ATI communicate perceived susceptibility, severity, threat, benefit, cue to action or motivation in public health professional users for the selected outbreak pathogen or prescribed health regime?" The null hypothesis is that public health professional users of the AOP ITS with ATI will be ambivalent about the perceived susceptibility (PS), severity (PSV), threat (PT), benefits (PB), cues to action (CA) or motivation (M) toward the selected pathogen or prescribed health regime. Like the TAM, the HBM used a Likert 7-point response scale (Table 7). Data collection for Hypothesis D is contained within the survey tools in section 4 of the tutor course flow.

Hypothesis E. Our fifth research question is, "Does an AOP ITS using ATI attract invited public health professionals to receive public health professional's knowledge and application to meet a pathogen outbreak scenario?" The null hypothesis is that public health professionals will not voluntarily engage in non-mandatory training for the given pathogen outbreak scenario. This hypothesis is addressed through the response level of invited public health professionals to partake in various training stages. Data collection for Hypothesis E was conducted utilizing a non-participation survey tool presented in the recruitment invitation composed in Qualtrics (Qualtrics, 2020).

Data was extracted from the GIFT and Qualtrics platforms. Microsoft Excel and IBM SPSS Statistics software package were used in data analysis (IBM, 2018). The Wilcoxon signed-ranks test is a non-parametric equivalent of the paired *t*-test. It does not assume normality in the data and is used to compare paired observations by testing difference in mean or median. In our analysis we utilize the median. There are 3 assumptions that must be met to use the Wilcoxon Signed Ranks Test. The first assumption is that your dependent variable is measured at the ordinal or continuous level. Our data utilizes 7-point Likert items (Tables 5 and 7). The second assumption is that the dependent variable should consist of two categorical related groups or matched pairs. We utilize the same study participants for the pre- and post-assessment evaluations. The third assumption is that the distribution of the differences between the two related groups needs to be symmetrical in shape (LAERD, 2018; Influential Points, 2020). In our hypothesis testing methods, our One-Sample Wilcoxon-Signed Rank test value was "4" which represents "neither disagree or agree" and "neither" in the response scales for TAM and HBM, respectively. We utilized power at $\alpha = 0.05$ and $\beta = 0.4$ with confidence intervals of 95%. Significance and decision results are shown in Tables 6 and 8.

3. Results

The pilot study contained 2 focus groups totaling 17 public health professionals from two local county health departments, all with varied experience in surge events. Focus group sessions had overwhelming positive responses and did identify and resolve some questionnaire and computer technical issues. More importantly, discussion revealed that ATI remediation resulted in excessively longer length of ITS training than expected by some participants but also revealed gaps in user knowledge on using an ITS cloud-based platform. For the formal study, detailed information about how the ITS adaptively used ATI for remediation were communicated to participants through recruitment documents. A step-by-step user document (outside the ITS) and an ITS course navigation video demonstrated ITS tools and how to navigate within the course. Respondents also had the ability to contact the researchers to troubleshoot technology barriers or they could reply to the non-participation survey with the choice of "information technology barrier (i.e., system compatibility)."

Participation in the study was voluntary and resulted in the following number of participants at each stage: 940 invitations were sent to national, state and local public health professionals, 179 made course queries, 129 signed informed consents, 104 completed learner attributes surveys, 97 completed pre-test assessments, 73 completed the course and application scenario question, 72 completed the post-test assessment, and 69 completed the technology acceptance model survey and the health belief model survey. There were 42 participants who did not make a course query but did complete a non-participation survey discussed below.

The 69 participants that completed the course and the surveys in their entirety form the cohort used to address hypotheses A through D. Our study population profile mirrored the results of other public health workforce studies as displayed in Table 1 (Jones, Banks, Plotkin, Chanthavongsa, & Walker, 2015). 68% of participants reported experience with content contained in the ITS which is practical for remediated instruction.

Table 1. Demographic data study of participant cohort (n = 69)

Mean age (yrs.)	Age range (yrs.)	Gender (n)		Mean experience (yrs)	Experience range	Experience with Rash Illness (n)	
		Female	Male			Female	Male
43.7	24-69	52 (75%)	17 (25%)	15.7	1-45	47 (68%)	22 (32%)

Note. Demographic data of the study population mirrors the results of other public health workforce studies.

Hypothesis A: Preference for obtaining knowledge. In a comparative analysis, we asked participants if time would have been better spent on researching the content on the internet, talking with a knowledgeable mentor or taking a class with a discussion group rather than taking the course on the ITS platform. The ITS platform was significantly preferred over the 3 choices (Table 2).

Table 2. Comparison-Time would have been better spent with Internet search, Knowledgeable Mentor or Class Discussion Group rather than ITS (n = 69)

Response	Internet search (n)	Knowledgeable mentor (n)	Class discussion group (n)
Yes	11(15.9%)	25 (36.2%)	18 (26.1%)
No	58 (84.1%)	44 (63.8%)	51 (73.9%)

Note. Comparative analysis of methods for obtaining content contained in the ITS platform demonstrates that the ITS is consistently preferred over the 3 methods presented.

Hypothesis B: Knowledge acquisition and application. The competency level of study participants using an ITS and packing and shipping clinical specimens for rash illness are at the lower end of the Brenner Scale while the competency in managing a patient with rash illness shows equality across novice, competent and proficient categories (Table 3).

Table 3. Competency Level of using an ITS, managing a patient with rash illness, packing, and shipping clinical specimens for rash illness (n = 69)

Skill	Novice (n)	Beginner (n)	Competent (n)	Proficient (n)	Expert (n)
ITS	45 (65.2%)	15 (21.7%)	6 (8.7%)	3 (4.3%)	0
Pt Rash	19 (27.5%)	9 (13.0%)	19 (27.5%)	19 (27.5%)	3 (4.3%)
Pack/Ship	25 (36.2%)	17 (24.6%)	19 (27.5%)	6 (8.7%)	2 (2.9%)

Note. Self-reported competency levels of study participants on the Brenner scale for using an ITS, packing and shipping clinical specimens for rash illness and for managing a patient with rash illness.

The average test scores for the pretest was 6.8 points or 68%, the average for the post test was 8.7 points or 87% ($p < .01$). The descriptive statistics show that there is an increase in scores from pre to post tests. The 25th percentiles saw an increase of 2 points, the 50th by 2 points and the 75th percentile by 2 points. The test statistics show that the ITS indeed demonstrates a statistically significant change in learning effectiveness ($Z = -6.05$, $p < .01$). There was a 288% increase for respondents to receive all 10 points and a 150% increase for respondents to receive 9 points. 20% of respondents improved their post test scores by 2 points, 19% by 3 points, 17% by 1 point, 10% by 4 points, 4% by 5 points, 1% by 6 points, and 1% by 7 points. Seventeen 17% percent ($N = 12$) of respondents did not show any increase or decrease in points when comparing their pretest to their post test scores. Seven percent 7% ($N = 5$) of respondents showed a decrease of 1 point and 1% ($N = 1$) a decrease of 2 points (Table 4). In the knowledge application scenario, 75% (52/69) of respondents were able to demonstrate their ability to apply the knowledge gained (Table 4).

Table 4. Scoring of assessments

Points	Pre-test (*n*)	Post test (*n*)	Change in points (*n*)	% Change from Pre to Post	Scenario (*n*)
-2	N/A	N/A	1 (1%)		
-1	N/A	N/A	5 (7%)		
0	0	0	12 (17%)	0	17 (25%)
1	0	0	12 (17%)	0	52 (75%)
2	1 (1%)	0	14 (20%)	-100%	
3	2 (3%)	2 (3%)	13 (19%)	0%	
4	9 (13%)	2 (3%)	7 (10%)	-78%	
5	4 (6%)	0	3 (4%)	-100%	
6	10 (14%)	1 (1%)	1 (1%)	-90%	
7	15 (22%)	6 (9%)	1 (1%)	-60%	
8	14 (20%)	12 (17%)	0	-14%	
9	6 (9%)	15 (22%)	0	150%	
10	8 (12%)	31 (45%)	0	288%	

Note. Based on the scoring assessment data, an AOP ITS using ATI supports skill and competency training for public health professionals.

Hypothesis C: Technology Acceptance Model concepts. Learner perception levels for the TAM concepts were measured using the scale shown in Table 5. Results are graphically displayed in Figure 1. Inferential comparisons of TAM concepts to ambivalence of use are displayed in Table 6.

Table 5. Technology Acceptance Model response scale

1	2	3	4	5	6	7
Extremely Disagree	Disagree	Slightly Disagree	Neither disagree or agree	Slightly Agree	Agree	Extremely Agree

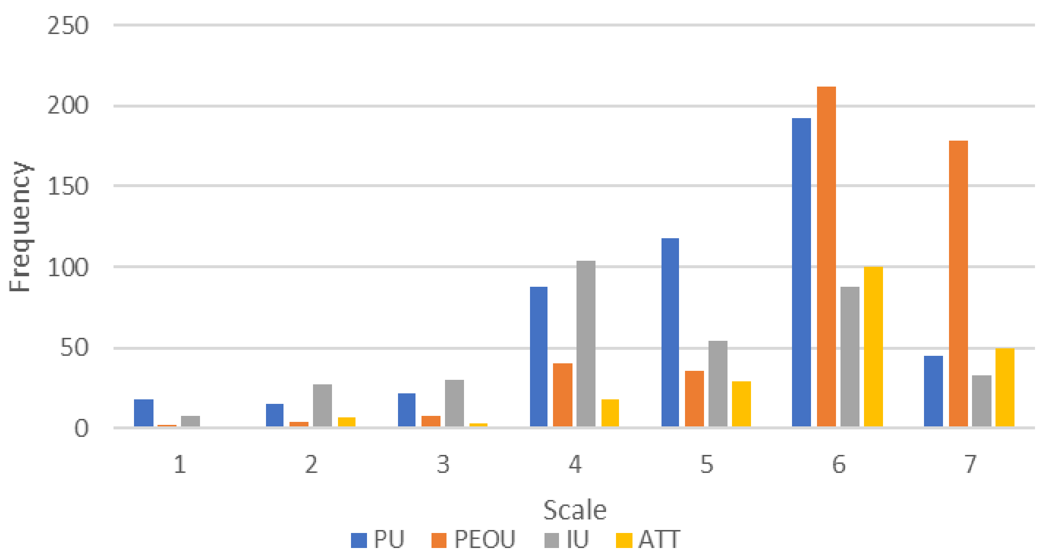

Figure 1. TAM Aggregate Data (*n* = 69).

Results in Figure 1 and Table 6 indicate that public health professionals are not ambivalent but rather in agreement in using an AOP ITS as it correlates to PU, PEOU and ATT as the mode of their responses on each concept was "Agree." However, there is a level of ambivalence in IU particularly in the temporal indicators for future use (i.e., over the next 3 months).

Table 6. One-sample Wilcoxon Signed Rank Test TAM concepts

Model concepts	Indicators	Label	$\alpha = 0.05$	H_0	$\beta = 0.4$	H_0
Attitude						
	Good idea to Use	ATT1	$p < .01$	Reject	$p < .01$	Reject
	I like the idea to Use	ATT2	$p < .01$	Reject	$p < .01$	Reject
	Using it is a pleasant experience.	ATT3	$p < .01$	Reject	$p < .01$	Reject

Perceived ease of use						
	Easy to Operate	PEOU1	$p < .01$	Reject	$p < .01$	Reject
	Easy to do what I want it to do.	PEOU2	$p < .01$	Reject	$p < .01$	Reject
	Interaction was clear and understandable	PEOU3	$p < .01$	Reject	$p < .01$	Reject
	Flexible to interact with.	PEOU4	$p < .01$	Reject	$p < .01$	Reject
	Easy to become skillful at using	PEOU5	$p < .01$	Reject	$p < .01$	Reject
	Overall, easy to use	PEOU6	$p < .01$	Reject	$p < .01$	Reject
	Over the last 12 months, easy to use.	PEOU7	$p < .01$	Reject	$p < .01$	Reject
Perceived usefulness						
	Enable to accomplish tasks more quickly.	PU1	$p < .01$	Reject	$p < .01$	Reject
	Improve my job performance	PU2	$p < .01$	Reject	$p < .01$	Reject
	Increase productivity.	PU3	$p < .01$	Reject	$p < .01$	Reject
	Enhances effectiveness on the job	PU4	$p < .01$	Reject	$p < .01$	Reject
	Easier to do my job.	PU5	$p < .01$	Reject	$p < .01$	Reject
	Overall, useful in my job.	PU6	$p < .01$	Reject	$p < .01$	Reject
	Over the last 12 months, useful in job.	PU7	$p < .01$	Reject	$p < .01$	Reject
Intention for use						
	Intend to use it for training.	IU1	$p < .01$	Reject	$p < .01$	Reject
	Predict will use it for training.	IU2	$p < .01$	Reject	$p < .01$	Reject
	Expect to use it.	IU3	$p < .01$	Reject	$p < .01$	Reject
	Over the next 3 months, expect to use	IU4	$p = 0.183$	Retain	$p = 0.183$	Retain
	Over the next 3 months, intend to use	IU5	$p = 0.91$	Retain	$p = 0.91$	Retain

Note. Public health professional ambivalence levels toward "Attitude," "Perceived Ease of Use," "Perceived Usefulness" and "Intention for Use." Ambivalence could NOT be rejected for the following dimensions of "Intention for Use": Over the next 3 months, expect to use and Over the next 3 months, intend to use.

Hypothesis D: Health Belief Model concepts. Learner perception levels for the HBM concepts were measured using the scale shown in Table 7. Results are graphically displayed in Figure 2. Inferential comparisons of HBM concepts to ambivalence of use are displayed in Table 8.

Table 7. Health belief model response scale

1	2	3	4	5	6	7
Extremely Unlikely	Unlikely	Slightly Unlikely	Neither	Slightly Likely	Likely	Extremely Likely

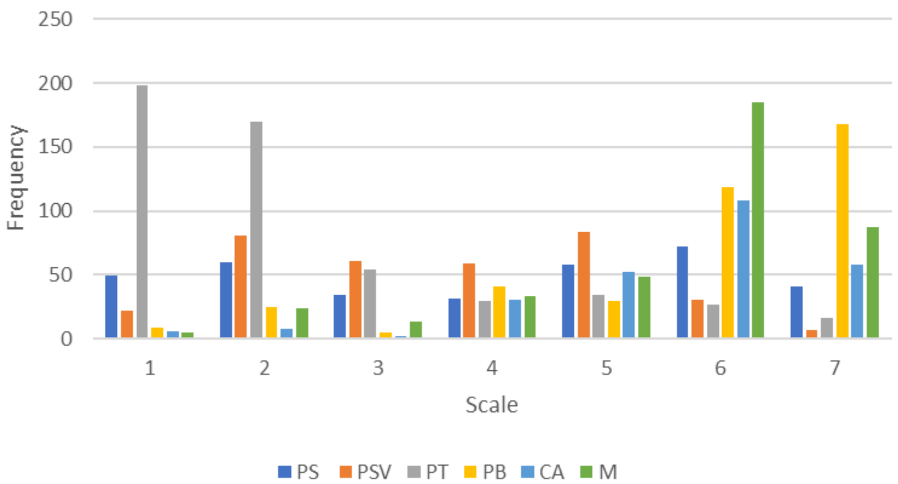

Figure 2. HBM Aggregate Data ($n = 69$)

Table 8. One-Sample Wilcoxon Signed Rank Test HBM Concepts

Model concepts	Indicators	Label	$\alpha = 0.05$	H_0	$\beta = 0.4$	H_0
Perceived susceptibility	Chances of getting a febrile rash illness	PS1	$p < .01$	Reject	$p < .01$	Reject
	Chance of community febrile rash illness outbreak in the future	PS2	$p < .01$	Reject	$p < .01$	Reject
	Likelihood community exposure to an outbreak	PS3	$p < .01$	Reject	$p < .01$	Reject
	Over last 12 months, myself susceptible to a febrile rash-like illness.	PS4	$p < .01$	Reject	$p < .01$	Reject
	Over last 12 months, community susceptible to rash illness outbreak	PS5	$p < .01$	Reject	$p < .01$	Reject
Perceived severity	Over the last 12 months, severity of infection	PSV1	$p = .007$	Reject	$p = .007$	Reject
	Over the last 12 months, experience long term problems from infection	PSV2	$p < .01$	Reject	$p < .01$	Reject
	Severity of the illness on community	PSV3	$p = .007$	Reject	$p = .007$	Reject
	Community experience long term problems from that outbreak	PSV4	$p = .014$	Reject	$p = .014$	Reject
	Over the last 12 months, community severity of outbreak	PSV5	$p = .41$	Retain	$p = .41$	Retain
Perceived threat	Over the last 12 months, afraid for myself to have the lab testing done	PT1	$p < .01$	Reject	$p < .01$	Reject
	Over the last 12 months, be afraid to perform lab testing for community	PT2	$p < .01$	Reject	$p < .01$	Reject
	I do not know the accurate lab tests required for febrile rash illness.	PT3	$p < .01$	Reject	$p < .01$	Reject
	The laboratory tests required for febrile rash illnesses are not reliable.	PT4	$p < .01$	Reject	$p < .01$	Reject
	Preventing rash illness is next to impossible for myself	PT5	$p < .01$	Reject	$p < .01$	Reject
	Preventing rash illness is next to impossible for the community	PT6	$p < .01$	Reject	$p < .01$	Reject
	Over the last 12 months, threat to myself to be infected	PT7	$p < .01$	Reject	$p < .01$	Reject
	Over the last 12 months, threat to my community to be infected	PT8	$p = .002$	Reject	$p = .002$	Reject
Perceived benefits	Important to know how to stay healthy.	PB1	$p < .01$	Reject	$p < .01$	Reject
	Important that my community knows how to stay healthy	PB2	$p < .01$	Reject	$p < .01$	Reject
	Understanding content decreases chances of exposure for community	PB3	$p < .01$	Reject	$p < .01$	Reject
	Understanding content decreases chances of exposure for myself	PB4	$p = .538$	Retain	$p = .538$	Retain
	Over the last 12 months, training myself will be a benefit to me	PB5	$p < .01$	Reject	$p < .01$	Reject
	Over the last 12 months, training myself benefits my community	PB6	$p < .01$	Reject	$p < .01$	Reject
Cue to action	Gaining more knowledge on a topic would improve confidence	CA1	$p < .01$	Reject	$p < .01$	Reject
	Learning about technology from others influences my use of it.	CA2	$p < .01$	Reject	$p < .01$	Reject
	Learning in a self-paced environment influences my use of technology.	CA3	$p < .01$	Reject	$p < .01$	Reject
	Communication from colleagues about technology influences my use.	CA4	$p < .01$	Reject	$p < .01$	Reject
Motivations	General concern about my health.	M1	$p = .004$	Reject	$p = .004$	Reject
	General concern for health of	M2	$p < .01$	Reject	$p < .01$	Reject

community					
Frequently do things to improve health	M3	$p < .01$	Reject	$p < .01$	Reject
Frequently do things to improve health of community	M4	$p < .01$	Reject	$p < .01$	Reject
Search for new information related to health	M5	$p < .01$	Reject	$p < .01$	Reject
Search for new information related to keeping community healthy	M6	$p < .01$	Reject	$p < .01$	Reject

Note. Public health professional ambivalence levels toward "Perceived Susceptibility," "Perceived Severity," "Perceived Threat," "Perceived Benefits," "Cue to Action" and "Motivations." Ambivalence could NOT be rejected for the following dimensions of "Perceived Severity" and "Perceived Benefits" respectively: Over the last 12 months, community severity of outbreaks and Understanding content decreases changes of exposure for myself.

Results from the Wilcoxon signed-rank test indicate that public health professionals are not ambivalent in using an AOP ITS as it correlates to the HBM concepts of PS, PT, CA, and M. The mode of their responses on the concepts of PS, CA and M was "Likely" but for PT was "Extremely Unlikely". Respondents are not ambivalent for 4 of the 5 indicators for PSV with the mode of "Slightly Likely." The fifth indicator is temporal on the severity of an outbreak on the community and does indicate ambivalence. Respondents are not ambivalent for 4 of 5 indicators for PB with the mode of "Extremely Likely." There is ambivalence on 1 indicator as it pertains to perceived benefits about learning about the content of the ITS to decrease exposure to self.

We further stratified our analysis for PS, PSV, PT and PB in terms of perceptions of self-versus the community. We found for PS the mode toward self as "Unlikely" but toward community as "Likely." For PSV, the mode toward self was "Unlikely" and toward the community was "Slightly Likely." For PT, the mode toward self was "Extremely Unlikely" and toward community was "Unlikely" and for PB "Extremely Likely" for self and for the community.

Our results also revealed that public health professionals are highly influenced to use new technology if they learn about it from others if it is in a self-paced environment and if their colleagues communicate about it to them.

4. Discussion

This article contributes to understanding of adaptive learning with an AOP ITS using ATI hosted on a freely available GIFT platform that could be rapidly created and disseminated to educate the public health workforce in order to stem the adverse effects on a society of a pathogen outbreak or pandemic.

Our research instantiated that an AOP ITS using ATI is a pedagogy suitable for public healthcare professionals. While the content and pedagogy addressed measles and varicella pathogen management, the ITS can deliver content for management of COVID-19 or any other pathogen. Further, the ITS actively tests not only knowledge level but application of knowledge in a scenario that could be applied in an outbreak. Administratively this helps public health professionals confirm skill and competency.

Respondents' perception of susceptibility and severity of illness from rash illnesses was greater for the community than self. Their perceptions of threat for self and community was also improbable as a mechanism for prevention is possible (i.e., vaccination). Respondents agreed that they were motivated to learn about how to keep self and their community healthy and that there were benefits from learning this information on an ITS platform including gaining more confidence in work performance. Being online on a cloud platform, the ITS may deliver training at scale, anytime, anywhere in a cost-effective manner, decreasing the demand for expert human mentors.

The 69 person cohort who completed the course were motivated, found the platform useful and would likely return to it in the future as well as advised that it was preferential when compared to an internet search, class discussion, and even a one-on-one interaction with a knowledgeable mentor. These public health professionals largely agreed that the ITS was useful, easy to use, and had a positive attitude toward its use. The ITS most helped respondents who identified below proficient level of competency on the Brenner scale (i.e., Novice, Beginner) as they demonstrated the greatest learning improvement.

In terms of an outbreak or pandemic, our results reveal that our study population has sufficient motivation that febrile rash illness is relevant, that they believe the community is susceptible to a serious health problem and that the use of the AOP ITS would be beneficial in reducing the threat of illness to the community.

Of the limited published literature in scholarly journals, an ITS typically induces pre to post student learning improvements in the range of 0.25 to 1.0 standard deviation (Kulik & Fletcher, 2016). Our study reports an overall 1.00 standard deviation pre to post improvement for our 69-person cohort signifying significant learning effectiveness using ATI with remediation. For understanding the context of theoretical power and alpha error, volunteer-based sampling is non-probabilistic and therefore there is no formula for computing the required sample size and the traditional N = 30 should suffice (Ritter & Sue, 2007). However, Bujang and Baharum (2016) indicate N = 61 yields $R_0 = 0.0$, R_1 (alternative hypothesis) = 0.4 for correlation tests with a power of 90% and alpha of 0.05. Cohen (1992) indicates N = 64 detects a mean difference medium effect size (.5 standard deviation) with a power of 80% and alpha of 0.05. The 69-person cohort coupled with a full standard deviation improvement exceeds either recommendation. The 69-person cohort is also favorable considering other published ITS research using only 11 to 58 volunteers for analysis (Davidovic, Warren, & Trichina, 2003; Folsom-Kovarik, Schatz, & Nicholson, 2010; Mcquiggan, Mott, & Lester, 2008).

5. Limitations

A cross-sectional study design has inherent disadvantages as it is designed to capture a specific moment in time which may not be representative of behaviors of our study population over time. It also does not help determine cause and effect very well. We did try to control for these disadvantages by asking temporal questions when it came to usage but our respondent group although willing to use the technology in the future were not able to make affirmative choices for use 3 months into the future.

Respondents identified one significant limitation. Although the course content is taken from the nationally recognized authority on notifiable diseases and conditions, application to the nation may be limited. As with all notifiable conditions it is up to the state to adapt their methods for validation and evaluation (CDC, 2019).

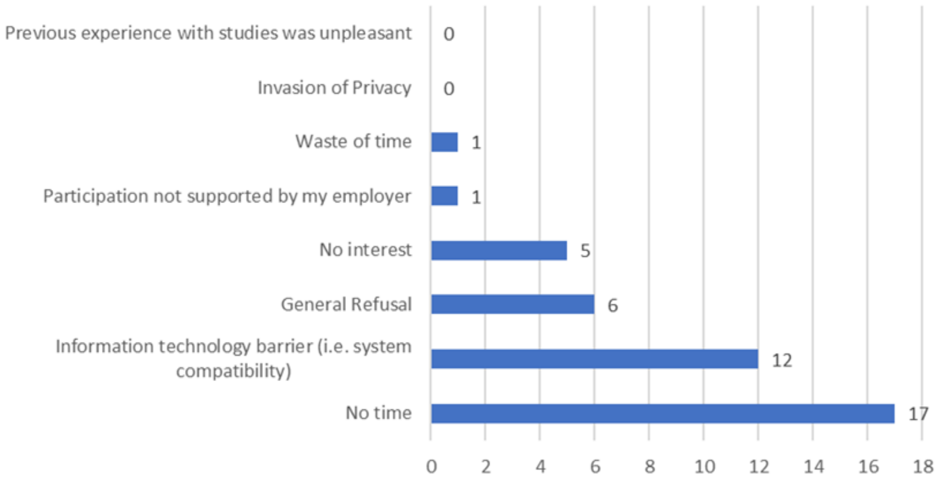

Figure 3. Public health professionals' non-participation in voluntary research (n = 42)

69 participants from 940 invitations indicate limited reach on a voluntary basis of an ITS among the public health workforce. To better understand the 81% non-participation rate, forty-two respondents who did not participate in the study did provide feedback as to why they did not participate (Figure 3). 40% (17/42) identify "no time" and 29% (12/42) identify "information technology barriers (i.e., system compatibility issues)." These two most cited reasons were also validated by email and telephonic discussions. Statistically, Bujang and Baharum (2016) indicate N = 46 yields an $R_0 = 0.0$, $R_1 = 0.4$ for correlation tests with a power of 80% and alpha of 0.05. Interpolation of Bujang and Baharum (2016) scale for 42 participants infers a theoretical R1 of .43. Cohen (1992) indicates N = 38 detects a large effect size (.8 standard deviation) mean differences with a power of 80% and alpha of 0.05. 42 respondents coupled with the proportions in two non-participation reasons provide assurance these were the most important reasons for non-participation.

In terms of time, non-participating public health professionals advised that they had too many commitments at work to commit the 30 minutes expected for this research. That infers to reach greater proportions of public healthcare workers, the ITS must be required to be used. Additionally, 179 opened the introduction to the course but the expected 30-minute time for training also proved too optimistic. For the 69-person cohort, not counting one outlier who took 291 minutes to complete the course, the median time of completion of the remaining 68 participants was 46 minutes with a range from 11 to 115 minutes. It is assumed that those spending the greatest amount of time in the system needed the greatest amount of remediation. For the remaining 110, the 30-minute time expectation for the course and the possibility of the course exceeding 30 minutes may explain as much as 2/3rds who did not complete the entire course.

Information technology barriers may also explain as much as 1/3 of the 110 who reneged on completing the course. Specifically, some individuals needed additional instruction on how to connect to the platform and to perform functions within the platform once accessed despite the fore mentioned navigation video explaining connection and use of the platform. More importantly, email communications during the study and the free text responses in the surveys showed that many respondents had course terminations not by their own choice. Many stated that the course "shut down on its own," would "not allow completion of the process" or would "not move forward or continue." Later analysis revealed that many health departments do not allow access to cloud applications of this type through their organization firewall. Additionally, many health departments rely on Windows Explorer browsers at their workstations. The prototype used in this research was compatible with Chrome, Edge, or Firefox browsers, not Windows Explorer.

6. Conclusions and future research

Our research indicates that volunteer public health workforce participants completing health regime pathogen outbreak or pandemic training using an AOP ITS with ATI remediation were not ambivalent about the use of the technology. Rather, the synchronous-agent-student engagement facilitated by the ITS design was significantly preferred by participants to an Internet Search, a Mentor, and Classroom discussion. By extension, the inherent scalability, flexibility, and cost effectiveness of the design may also reach but better engage remote learners than the asynchronous e-learning methods currently employed during the COVID-19 pandemic. Further, knowledge increased at a statistically significant amount with volunteers able to effectively apply regimes in an application scenario. Participants perceived the ITS easy to use, useful, and were positively inclined toward it. Additionally, participants were positively inclined toward the ITS particularly toward the HBM concepts of "Perceived Susceptibility," "Perceived Threat," "Cue to Action" and "Motivations." These findings infer the ITS technology may make a significant impact on preparing local and remote workforces to detect, prevent, and respond to public health surge capacity events while providing managers assessment of an individual's competency with a regime in application scenarios.

Research revealed shortcomings including participants ambivalence about "Perceived Severity," "Perceived Benefits," and their "intention to use" the technology in the future. Better understanding the nature of these ambivalences needs future research. These perceptions coupled with the high non-participation rate, forces acceptance of the null hypothesis that for the most part, public health professionals will not voluntarily engage in non-mandatory ITS training for the given pathogen outbreak scenario. By extension, these findings infer limited potential for an AOP ITS using the current ATI paradigm to make a major contribution to adding public health workforce surge capacity unless workforce members are directed to utilize it and technology barriers in the current public health IT infrastructure are overcome.

Findings on time limitations, participant availability limitations, and local constraints also infer future research to better understand how best to address time and availability issues as well as the extent of customization imposed by unique state and organizational governance.

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