Intelligent Tutor System for Laboratory Testing for Febrile Rash Illness

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INTRODUCTION

Outbreaks are localized events that can quickly overwhelm local health departments' ability to respond effectively. It is imperative that local departments can quickly prepare and deploy skilled responders once an initial case of a communicable disease is detected. Since outbreaks tend to occur sporadically, continuous training and preparation is necessary.

In the case of infectious diseases, proper adherence to protocols and any additional disease specific guidelines is critical to ensure the safety of the public. While licensed health professionals are trained on various aspects of infectious disease care, treatment and precautions; protocols tend to evolve and improve with time.

Medical errors due to insufficient or not current training by a medical professional may result in harm to the patient, consume additional resources, result in improper records or potentially contaminate clinical samples and even spread the infection. There are several psychological components such as prior knowledge of task, problems related to teamwork, communication, technology design, leadership and human decision making that determine the likelihood of error. Therefore, along with knowledge it is also important to understand attributes of the learner that may impact performance of task while being tested on the subject matter.

In this paper, we describe an Intelligent Tutoring System (ITS) utilizing the Generalized Intelligent Framework for Tutoring (GIFT) platform. The ITS was developed to enhance the local health authority's consultation and training responsibilities when responding to an infectious disease outbreak. The ITS assesses learner attributes via a pre and post knowledge assessment. The knowledge assessment checks on the learners' ability to recognize illness and order appropriate clinical testing to identify or rule out cases of communicable febrile rash illnesses in a timely manner. To order appropriate clinical testing, health care workers need to appropriately collect, store and ship diagnostic specimens to the state public health laboratory. Measles and Varicella are two communicable febrile rash illnesses that will be used to exemplify the processes in this paper.

Measles Sample Collection

Sample collection procedures during measles response outbreaks require significant understanding of the disease and protocols for collection and processing of clinical samples. The trainee must know the methods to detect measles infection and immunity. Measles virus can be detected from various samples by using cell culture techniques or molecular techniques. Measles identification methods are as follows; Serological assays including Immunoglobulin M (IgM) enzyme-linked immunosorbent assay (ELISA), Virus isolation and Reverse transcription polymerase chain reaction (RT-PCR). Throat (Oropharyngeal), nasal or NP (nasopharyngeal) swabs are the preferred samples for virus isolation or detection of measles RNA by RT–PCR. Synthetic swabs are recommended. Urine samples may also contain virus and when feasible to do so, collection of both samples can increase the likelihood of detecting the virus. Samples should be collected as soon after rash as possible or at the first contact with the suspected case. To assess for measles immunity in contacts (persons exposed to suspected case), the serological assays are utilized to test for IgM and IgG (Centers for Disease Control National Center for Immunization and Respiratory Diseases, 2015).

Varicella Sample Collection

Skin lesions are the preferred specimen for laboratory confirmation of Varicella virus. The swab is taken from the base of a wet lesion. Two filled in dime sized circles should be made on a plain glass slide and allowed to air dry. Two slides should be collected from each patient. Serum specimens are preferred to test for immunity (IgG). IgM testing may be performed on unimmunized subjects or on subjects with unknown immunity status. Blood specimens are collected using a vacutainer with a red stopper or serum separator tube.

Several methods including the isolation of varicella virus from a clinical specimen, direct fluorescent antibody (DFA), polymerase chain reaction (PCR) or detection of significant rise in serum varicella IgG by any standard assay meets the laboratory criteria for diagnosis. Specimens and the manner of collection for each may vary. Thus, the health professional needs to follow the exact procedure to safely and reliably collect and ship the clinical specimens. Additionally, demographic information about the subject and the clinical sample needs to be appropriately recorded on the specimen label (Centers for Disease Control National Center for Immunization and Respiratory Diseases (NCIRD), 2017). There are many areas in which errors can occur during the processing of clinical specimens. Training and refresher training can help reduce error.

Regulatory guidelines are updated by the State and Federal levels and can be located at the State Public Health Department and the Centers for Disease Control (CDC) websites. Training materials are generally available in various mediums from various medical sources including the State Health Department and CDC. Frequently, the responsibility for collating, curating and presenting the content to medical professionals falls on the local health officials. These duties may create additional burden especially during outbreak responses when the need for training is great and the resources to train may be allocated elsewhere.

Why use an ITS platform

Training or review provided at the start of outbreak takes time and resources away from the response. There are limited methods to assess the readiness of responders prior to their deployment to a response area. The department lead is often responsible for staff training and preparedness. However, in a classroom mode of training it is a challenge for even experienced teachers to personalize instruction and keep track of learner ability, prior knowledge and progress.

The Generalized Intelligent Framework for Tutoring (GIFT) platform allows for on demand personalized tutoring that can assess and tutor several health care workers without additional demands on local resources. The ability to author content, set up adaptive surveys based on learner performance and attributes may significantly improve learning outcomes for many health care workers ultimately improving the quality of response and delivery of care.

Learner attributes are intrinsic to the way each individual processes and assimilates information presented. The ability of a tutor to perceive learner attributes either by observation or by assessment and formulate content delivery based on these perceived attributes can greatly enhance learner engagement and improve learner outcomes. For this reason, we choose the Generalized Intelligent Framework for Tutoring (GIFT) as an Intelligent Tutoring System (ITS) for this tutorial. GIFT is a computer based tutoring system that incorporates a learner and a pedagogical module as part of the GIFT Authoring Tool

(GAT). These modules allow testing for adapting instruction to specific learner attributes by using specific learner states to select the next content to be presented to the learner (Sottilare, Grasser, Hu, & Brawner, June, 2015).

The ITS for Laboratory Testing for Febrile Rash Illness assumes the learner is a qualified healthcare professional that is familiar if not well versed in the content presented. The objective of the tutor is to provide refresher training on an as needed basis to the individuals who may not have collected the clinical samples recently. Therefore, the ability to assess prior knowledge and deliver content as needed prevents redundant training while identifying and tutoring only those individuals in need of additional support.

RESEARCH HYPOTHESIS

Human tutors have collated, curated, provided and when needed presented training material to ensure health care workers have appropriate level of background knowledge and the ability to apply that knowledge in response to a health emergency. However, this can be a time-consuming process, with little to no ability to verify if each individual learner has met all the learning objectives. The primary goal in developing the tutor is to ensure high quality materials are personalized and presented to a learner based on their prior knowledge, grit and ability to learn.

The research hypothesis that is proposed for this ITS will provide the learner with an adaptive training environment that requires little to no human tutor involvement in training. It will also provide an assessment of the learner's understanding and ability to apply appropriate laboratory criteria for the testing of selected febrile rash illnesses.

Surveys and Course Evaluation Questionnaire

Learner's knowledge improvement is assessed by evaluation of their pre-and post-performance surveys. The surveys are indicative of the ability of a leaner to learn the subject matter presented by the ITS. To complete the testing of the hypothesis, learners' perception of the ITS course is recorded by the course evaluation questionnaire.

Related Research

E-Learning

There are several aspects that need to be considered in the design of web-based intervention including, patient adherence, interaction, condition, feedback target behavioral outcome and its evaluation (Kelders, Kok & Ossebaard, 2012a). These concepts are encapsulated in the persuasive design framework deployed by Lehto and Onias-Kukkonen (2011) in a system to assist recovery from alcohol and smoking recovery. The persuasive system design paradigm when properly implemented in an appropriately designed system causes behavioral changes in trainees. Principles of persuasive system design have been shown to increase adherence with protocol in trainees. Many of the applications of persuasive system design aim to modify behavior in patients who suffer from chronic conditions such as diabetes. The persuasive system design framework considers reduction, tunneling and tailoring mechanisms. Reduction is breaking complex behavior into its simplest form. Tunneling is putting the user through set experiences or processes designed to persuade the user. Tailoring is personalization of the content to the user's personality and needs. Additionally, the framework evaluates the system's ability to empower patient self-monitoring by the simulation of scenarios to rehearse the impacts of certain behavior. Single user interactive prompts such as praise, rewards, reminders, suggestion and liking are considered during system design for their impact on behavioral change. Social support aspects such as learning along with peers, either by comparison, cooperation or completion are considered along with other parameters such as recognition of achievement by peers. These web-based personalized medical simulation and serious gaming system have made the possibility of low cost patient specific care and protocol compliance system that promise to improve clinical quality outcomes and measures in the future a reality (Kelders et al. 2012b).

Serious Gaming

Studies have shown that serious gaming can enhance learning outcomes and improve real world performance when used to train emergency medical responders (Knight et al., 2010). Several serious games that immerse the trainee in various disaster or surge event scenarios have been found to positively impact trainee preparedness for the real event. These scenarios include mass causality events triage (Pelaccia et al., 2009 ; Knight et al., 2010) mass causality burn events (Kurenov et al., 2009) and disaster response drills that utilize virtual reality technologies (Breslin et al., 2007). Recently, serious gaming tools especially online multi-player games have proven to be effective in planning for response (Breslin et al., 2007) while task simulators for the purpose of training are now well established in health care (Craft, Feldon & Brown, 2014).

Merrill's Component Display Theory

Component display theory (CDT) due to its precise matching of content classification with leaner performance is well suited for computer based training. The theory postulates that instructional outcomes can be classified on two dimensions: student performance and subject matter content. The CDT ties together performance categories with content categories and tests the learners' ability to understand and apply principles broadly when required. Performance categories include the ability to recall (remember), apply (use) and ultimately identify new situations not described in the tutor and apply concepts explained in the tutor (find). Content categories include the ability to retain facts, develop conceptual understanding, and describe task procedures (sequence). These interrelationships are presented in a performance / content matrix that can be developed for any given cognitive learning scenario. A limitation of the CDT is that it does not assess psychomotor tasks and affective objectives (Merrill, 1983).

Instructional presentation in the ITS are comprised of a series of discrete survey questions, displays and media presentations. The presentation of the material has two dimensions: content mode (generality or instance) and presentation mode (expository or inquisitory).   The tutor developed is based on the primary presentation forms that combine generality with Expository (rules) and then with Inquisitory (recall) and test the generalities using instances with Expository (examples) and Inquisitory (practice). The survey object available in GIFT is an implementation of this theory (Sottilare, Grasser, Hu, & Brawner, 2015).

ITS DESIGN AND STRUCTURE

Tutor Process Overview

We developed an ITS using GIFT to facilitate training of medical staff in the laboratory testing of febrile rash like illnesses.   At the start of the course the learner is shown an introduction which advises the learner of the concepts that are covered in the course. After the introduction, the learner will be asked to complete an 11-question survey. The survey is a self-evaluation to ascertain the learner attributes as it relates to Knowledge, Prior knowledge, Grit, Skill and Learner Ability. The questions are in the format of multiple choice (2), True/False (1), and Likert 4 point scales. The multiple-choice questions are gathering information on the learner demographics and the two questions posed are "Please choose which age range that best describes you" and "Please use the range that best describes how many years you worked in a healthcare setting".

The learner completes the learner attribute survey and then is asked to complete a 25-question knowledge assessment. This survey is structured around the four concepts the ITS covers. The pre-test will be used in comparison with the post knowledge assessment to ascertain whether learning occurred. It will also be used to adapt the tutor so that the appropriate content is presented to the learner based on the performance of the learner. Regardless of the performance on the pre-test, all learners will be presented with the measles PowerPoint and the varicella PowerPoint. These slide sets contain the information on the four concepts and are set in the Rule Phase of the Adaptive Courseflow object. A schematic of the course flow is shown in Figure 1.

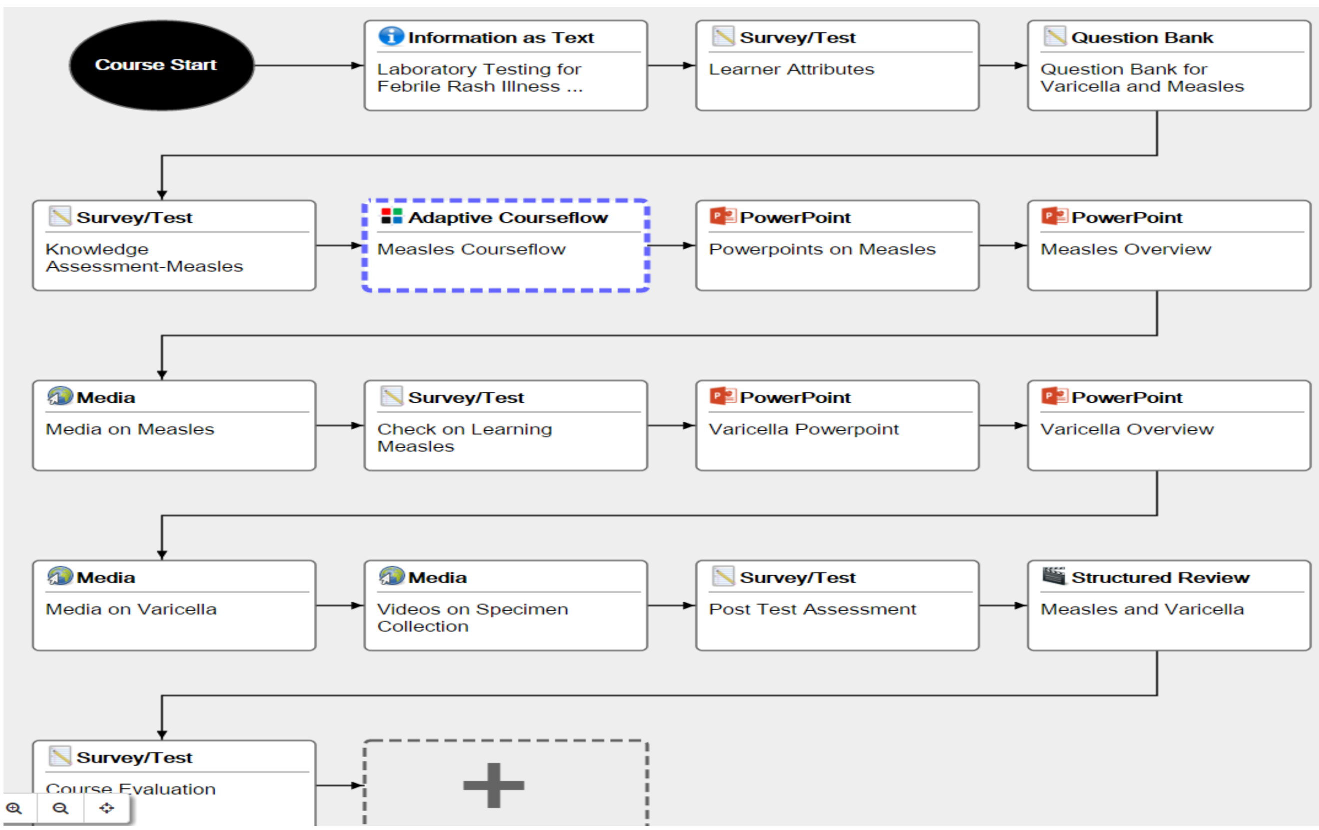

Figure 1: Laboratory Testing for Febrile Rash Illness Course Flow

If the learner is scored as a Novice or Journeyman from the Pre-Test assessment, he will be presented with content from the Example Phase which includes Overview PowerPoints on Measles and Varicella and 3 pieces of Media on each topic. If the learner scores as an Expert, after viewing the Measles PowerPoint, he will go immediately to the Check on Learning for Measles and then go into the Varicella PowerPoint. If the Check on Learning criteria is not met, the learner will be presented with the Rule Content again and have the option to select the Media Content to review. This will occur until the learner can successfully demonstrate understanding on the assessment surveys. Once the learner has completed reviewing the tutor content, he will be asked to complete a 25-question post knowledge assessment. This assessment is a duplicate of the pre-assessment.

Finally, the learner is presented with the Course Evaluation Survey. This is a 13-question survey that is composed of 5 point Likert Scale questions that range from Strongly Agree to Strongly Disagree and Free text questions. The purpose of this survey is to receive feedback from the learner on the ease of use of the system, the tutor content and if learning the content will led to a change in behavior.

Content Design

The guiding principle in our design of the current version of the ITS will be to test our proposed research hypothesis. Specifically, we will seek to ascertain if an ITS system can substitute a human tutor or minimize the human tutors' involvement for a public health response. As a first step the key concepts were identified as: Lab testing for Measles, Specimen and Lab Collection for Measles, Lab testing for Varicella (Chickenpox) and Specimen and Lab Collection for Varicella (Chickenpox). These concepts lend themselves to testing and assessment based on the principles in component display theory. We collated content and developed presentation paradigms for the expository rule and example phase. A decision was made to limit the current iteration to these four concepts and test the system before incorporating any additional concepts. Each of these concepts has content and media files associated with it that were collated from material that is generally made available to health care professionals.

The system was authored to provide all the necessary background information when needed based on the leaners' performance.

Survey Test Design

Two intake surveys were designed to assess the learner's attributes and prior knowledge. The adaptive course flow combines the rule and the example phase with the inquisitory recall and practice phase. For this tutor, we identified questions for the recall phase but did not include the practice phase as we were primarily interested in testing the ability of the learner to demonstrate retention and ability to apply key concepts that are covered in the expository phases.

DISCUSSION AND RECOMMENDATIONS

ITS design experience

The initial phase of the content development was focused on the development of material in appropriate format and medium to illustrate the key concepts. Once the expository content was selected and developed, as needed surveys were designed to test the proposed research hypothesis. The initial leaner attribute and prior knowledge survey were used to classify the user as a novice, journeyman or expert. This classification was used to drive the learners experience in the ITS environment. However, the system was developed with minimal ability to test the overall course flow. This limited our ability to iteratively improve the course flow and take full advantage of the adaptive course flow module.

A question bank comprising of the questions that test the knowledge of the learners on the concepts was developed. Individual questions were rated as easy, medium and hard and associated with specific concepts. Progression of content presented to the learner is determined by the performance of the learner on the questions. The number of easy, medium and hard questions that require correct responses is set in the recall phase of the adaptive course.

The post assessment evaluated the short-term retention of material covered by the tutor. Finally, the course evaluation survey captures user perception of the content, questions and the tutor system. The post assessment and the evaluation survey are designed to validate the research hypothesis.

Recommendations

An iterative design process separating content development and instructional design will help to fully leverage the abilities of the GIFT tutor and ensuring the tutor is consistent with the CDT. A formalized tutor development process will help the authors to develop testable tutors that are grounded in theory.

Content Development Process:

The content development process can be time consuming if not planned at the outset. This section outlines three recommendations that should help in development of course content.

1. Revision of the material and the survey to reduce total time it will take to complete the mandatory training. Once an initial draft of the material is prepared it is imperative to compute the total time it will take for the material to be presented to the learner in the ITS. If the total time exceeds thirty minutes a reduction of the material is recommended. In our experience including essential material for each concept for the initial draft of the course is helpful.
2. Division of the content into more discrete sections that correspond to specific learner objectives. It is helpful to set a finite maximum time for review of each section as per recommendations of the CDT. Base scoring on time taken to complete the assessment survey, especially the post assessment survey.
3. Classification of content and presentation element into primary presentation forms. The GIFT system can be improved by creating authoring templates or wizards for content creation. The wizard can, for example, guide the author through the content development process steps and provide recommendations for what needs to go into the rule, example, recall and practice phase.

Instructional Design Process:

The following five recommendations address the instructional design process for using GIFT for instruction.

4. Develop a performance – content matrix before implementation in the adaptive survey object. Select objectives based on intended performance- content level. The adaptive survey object requires planning before adding questions and associating questions with content. It will help to develop on paper a performance objective in terms of number of easy, medium and hard questions a learner needs to answer correctly. In this outline, include learner objectives associated with each performance measure to be tested in the adaptive survey. This will save time, prevent errors and allow more author control during the creation of the adaptive survey object. This will ensure that the adaptive survey object tests the learner on all the objectives and concepts that are covered in the content.
5. The GIFT system can be improved by providing a course dashboard that provides an overview of the documentation of prompts, listing the number of items, evaluation of survey questions for divergence and difficulty if based on the same concepts.
6. Consider timing and delay of post assessment or development of staged post assessment to assess impact on long term retention.
7. Development of novice, journey man, expert criterion.
8. Resolve other violations or infractions from the CDT.

System Development and Game based module

9. Development of a game based practice module (the practice will test instances of recall, procedure and location (this is a test that extends the CDT theory and would be an affective test / familiarization)

It is our intent to conduct a study to compare the GIFT tutor with a human tutor in terms of effort level required to train a group of learners for the course developed. There were technical issues at the time of writing of this paper which hindered full execution of the study. However, approvals for the study and recruitment of subjects has been initiated. Finally, a formal course design process will support creation of content by multiple authors. In many cases, courses are developed by author groups and a formal design process may help to accelerate the adoption of intelligent tutors in the author community.

There has been a dramatic increase in the number of e-learning and adaptive learning platforms tutors developed with consistent design based on theory that will allow for comparison between tutors. A future study concept would be to provide the same material using another freely online MOOCS tutor such as udemy.com and compare learning outcomes of that learner group to the group using GIFT.

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