An Assessment Tool and Interactive Simulation for Using Healthcare Personal Protective Equipment

by

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A thesis submitted in conformity with the requirements for the degree of Master of Health Science
Institute of Biomaterials and Biomedical Engineering
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Abstract

In healthcare, personal protective equipment (PPE) are sometimes misused due to improper skill acquisition or skill decay before clinical practice. Training is often didactic or web-based but it is unclear whether these methods transfer to effective physical performance. There is no standard method to evaluate these competencies and scheduling or space restrictions can limit physical practice. A Delphi survey produced relevant checklist and global rating items for evaluating use of PPE. Principles from skill learning and human-computer interaction were combined with the survey results to develop an interactive computer-based simulation for procedural practice of these skills. The assessment tool differentiated between experienced and newly-trained users and demonstrated inter-rater reliability. Learners rated their satisfaction with the simulation similar to a provincial online tutorial and pilot studies with the simulation demonstrated that learners practiced for a longer period when using the simulation as compared to the provincial online tutorial.
Acknowledgments

“The heights by great men reached and kept
Were not attained by sudden flight,
But they while their companions slept
Were toiling upward in the night.”

Henry Wadsworth Longfellow (1807–1882)

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Chapter 1
General Introduction

The transmission of healthcare-associated infections (HCAIs) is a major concern for most healthcare facilities. In Britain, 8% of patients admitted to hospitals are affected [1]; in the United States, HCAIs were the number one reportable disease for 2002 [2]; and in Canada, HCAIs are responsible for over 8,000 deaths annually [3]. These present physical, social, psychological and financial costs to patients and their families as well as financial costs to healthcare systems [4]. The appropriate use of personal protective equipment (PPE) such as gloves, masks, gowns and eye protection as well as performing hand hygiene are essential tools for healthcare workers to prevent or reduce the transmission of HCAIs to themselves and patients. Success in performing these procedural skills depends on knowledge of infection control techniques as well as understanding of infection control principles that inform routine and additional (airborne, contact, or droplet) precautions. However, the element of practice for acquisition and retention of procedural skills is often overlooked as many trainees receive only a lecture on infection control before being thrust into clinical environments with varied delays between lecture and practice. The reasons for the various formats of training programs largely depend on the availability of resources for instruction – time, space and other healthcare professionals or infection control experts to act as teachers – and there are no widely accepted guidelines for training or assessment.

Prompted by the emergence of complex simulations and smart games for various aspects of medical education, medial students were surveyed about their attitudes toward video games and new media technologies in medical education [5]. Most students were amenable to the idea of enhancing healthcare education using technology such as video games and believed that educators should utilize new media technologies more effectively for education. Additionally, the majority of respondents indicated that would use a multiplayer online healthcare simulation to accomplish an important learning goal. Despite the highly experiential benefits of such technologies, it is interesting to consider the applicability of a relatively simple computer-based simulation for practice of a procedural skill such as using PPE. Consequently, the objectives of this work were:

1) To identify key aspects of the skills involved with using PPE in healthcare;
2) To identify key performance indicators for highly skilled use of PPE;

3) To apply key aspects of the skills to the development of an assessment tool that can be used to evaluate PPE skills and in turn evaluate the effectiveness of education programs related to training PPE skills;

4) To apply key aspects of the skills to the design and development of an interactive computer-based simulation that will enable practice of PPE skills; and

5) To evaluate the perceived and actual utility of a computer-based simulation for practice of PPE skills.

This document has been organized as two articles for submission to academic journals. The target journals are identified at the beginning of each potential article. Realization of objectives 1, 2 and 3 are described in detail in Chapter 2 (the first article) while objectives 4 and 5 are described in Chapter 3 (the second article). Please note that for ease of referencing, figure and table numbering will be continuous throughout the document and not within each chapter/article.

The first four objectives were based on the identification of key aspects of PPE skills. This analysis was undertaken by conducting a Delphi survey of infection prevention and control experts across Canada. The Delphi was devised in the 1950s as a tool for determining military priorities and has since been utilized in a number of different fields [6]. Applications in healthcare include: identifying relevant diagnostic criteria for carpal tunnel syndrome [7], making recommendations regarding content and methods for maintaining competence of doctors [6], and identification of relevant competencies, skills and abilities for Navy nurse executives [8]. While there are many variations of the original technique [9], the basic premise is that investigators identify a question or issue and then generate an initial list of items that expand upon the question or issue, which is submitted iteratively to the members of the Delphi panel, who provide their opinions. This group process has the advantage of allowing busy professionals to participate by reducing the time and resources required to meet physically, which increases the likelihood of recruiting participants from more geographically and professionally diverse areas.

The application of the Delphi results to the development and evaluation of a simulation are described in Chapter 3. Methodologies utilized here included collection of data with human
participants, employment of observers who are infection prevention and control experts and the use of survey methods. Chapter 4 contains a general conclusion of the work described in the two previous chapters and potential implications for infection prevention and control education and computer-based learning programs.
Chapter 2
Development and Validation of an Assessment Tool for Skills Using Healthcare Personal Protective Equipment

Target Journal: American Journal of Infection Control

Keywords: Infection control, PPE, Delphi, checklist, global rating

1 Introduction

It is estimated that there are over 220,000 occurrences of healthcare-associated infections in Canadian hospitals that lead to over 8,000 deaths annually [3]. Important infection prevention and control (IPC) measures in healthcare include hand hygiene, nurse to patient ratio, patient accommodations, maintenance of equipment and use of personal protective equipment (PPE), which include items such as gloves, gowns, masks and various forms of eye protection. Use of PPE is a particularly interesting factor because even when PPE are employed, errors in the way they are used may reduce or negate their intended effects [10]. The route of transmission of the infectious agent, clinical activities and clinical environment determine choice of PPE. During the 2003 epidemic of SARS in Canada, it became evident that some healthcare worker infections may have been the result of improper use of PPE [11]. This highlights the fact that proper selection and use of PPE is an important factor for preventing and controlling the spread of infections to both patients and healthcare workers.

A survey of IPC competencies sought to identify objectives that are required for education of various hospital-based healthcare workers – nurses (registered, licensed practical and nurse practitioners), physicians and physician assistants, nursing assistants, respiratory therapists, physical/occupational therapists, environmental service workers, laboratory technicians and ancillary staff [2]. It was determined that proper hand hygiene, selection of appropriate PPE for each category of transmission-based precautions and demonstration of how to put on and take off PPE were required objectives for all hospital-based healthcare workers. However, in a recent review of checklists for assessment and certification of clinical procedural skills, investigators
found that one third of the checklists examined did not enable explicit assessment of ‘Infection Control’ competencies [12]. The authors noted that since assessment is a powerful driver for learning, these results raise questions about the value that learners attach to these components of clinical competency.

Assessment of clinical competence and the related task of assessing education programs is one of the most difficult tasks in health professions education. In the field of infection control, few studies [11, 13] have explored and compared the utility of various elements in education programs for transferring knowledge of selection and use of PPE; and even fewer have examined the long-term retention of PPE skills owing to such programs [14]. Infection control audits have been developed to examine practices and procedures in a clinical ward or service from a system perspective and have been shown to be beneficial to facility-wide infection control programs [15, 16]. However, audits do not directly assess a particular education program, nor are they able to directly assess the competence of a particular healthcare worker or health profession student. There is currently no widely accepted and standardized metric for assessing IPC competencies, particularly use of PPE and hand hygiene. Consequently, each study that undertakes evaluation of an IPC education program does so using a method of evaluation that is not validated, and the inconsistencies that may result are unknown.

The overall objective is to produce a validated PPE skills assessment tool in two phases: (i) tool development and (ii) tool validation. For the tool development phase of the project, the Delphi technique, which is utilized when experts are not physically gathered, was used. It is an iterative, multi-step process, geared towards building consensus on subjective factors with the goal of enhancing the individual opinions of experts and obtaining a collective expert opinion [6, 7]. Since panellists remain anonymous, the group process will not be unduly influenced by the reputation or opinion of any one panellist [7]. Subsequent to tool development, the tool was subjected to validation testing with PPE users of various levels of experience to determine its suitability for evaluating IPC education programs and trainees.

It was hypothesized that the developed tool would show that PPE users with more experience would perform better than newly-trained users. Additionally, it was expected that users’ scores would increase after practice and decrease one week after initial skill acquisition.
2 Development of Assessment Tool

2.1 Methodology

The protocol for tool development was classified as a program evaluation activity by the local Office of Research Ethics and did not require ethics approval. The protocol for tool validation obtained ethics approval from the local Office of Research Ethics.

2.1.1 Item Generation

The primary investigator generated an initial list of items describing the procedures for hand hygiene, donning and doffing PPE for routine practices in healthcare from three primary sources: (i) the Infection Prevention and Control Core Competency Education module in Routine Practices developed by the Ontario Ministry of Health and Long-Term Care [17] (webpage no longer available); (ii) federal and provincial guidelines for IPC in acute and long-term care facilities; and (iii) published academic and non-academic literature, media and online forums on the topic of PPE use. The initial list included both technique-specific checklist items that would be scored dichotomously and rating scale items that described global or holistic performance measures that would be scored on a five-point Likert scale. The checklist items were created to assess the sequence in which pieces of PPE should be donned and doffed, when hand hygiene should be performed and how each piece of PPE should be donned and doffed. Two local IPC experts, as determined by their professional positions in local healthcare organizations, were then consulted. The list was reviewed by these experts (the advisory committee) for errors then uploaded to Survey Monkey – a website that allows users to create and distribute web-based surveys (http://www.surveymonkey.com).

2.1.2 Selection of Delphi Panellists

In order to represent a wide range of opinions, Delphi panellists were recruited from a range of clinical disciplines and positions involved in regular use of and/or training in IPC. Prospective panellists were drawn from the following groups:

- Infection control and prevention instructors as identified in teaching hospitals or health professions departments in universities across Canada;
- Allied health or medical professionals who regularly practice infection control and prevention, recruited from teaching hospitals across Canada;
• Leaders in provincial and/or national health policy development regarding infection control, as identified by their roles with organizations such as provincial ministries of health, the Ontario Safety Association for Community and Healthcare as well as the Community and Hospital Infection Control Association – Canada; and

• Individuals who have authored one or more papers directly concerned with infection control quality or training in peer-reviewed journals.

Prospective panellists were contacted via electronic mail and provided with a letter detailing the purpose of the research and the methodology to be employed. Once an expert agreed to participate, he/she was assigned a unique participant number and supplied with an electronic link to the initial list of items on Survey Monkey. The membership of the panel was not disclosed to the participants/panellists or the advisory committee.

2.1.3 Item Evaluation and Data Analysis

In the first Delphi round, the panellists were asked to answer some demographic questions and then to rate and comment on the checklist and rating scale items as well as identify any additional performance indicators for PPE use. For each checklist and rating scale item, participants were asked to use a five-point Likert scale (completely unimportant | somewhat unimportant | neither important nor unimportant | somewhat important | extremely important) to rate the importance of that item for assessing PPE skills. For example, for a group of items regarding glove use, the questionnaire asked: “How important are the following items for assessing glove use when donning PPE?” Suggestions for additional items were added to the list of proposed items and revisions were made to any items that panellists identified as ambiguous or confusing. In the second round, the results were re-sent to the group, highlighting items that had achieved consensus and panellists re-rated the items. They used the same five-point Likert scale; however, they were also informed of the group median response, mode response, the range of responses and their response in the previous round. New responses to the items were recorded and repeated iterations of the process were carried out for a total of three rounds. The outcome of this process was the development of the PPE Skills Assessment Tool, which comprised: a checklist of specific technique-oriented steps (graded on a dichotomous scale – not done/done incorrectly or done correctly); and a global rating scale (GRS), reflecting overall competence on general aspects of the skill (graded on a numerical Likert scale, anchored by descriptive sentences).
The views of all participating experts were given equal weight. The results were analyzed using median and mode responses to determine which items reached either positive or negative consensus [18]. Positive consensus was defined as 80% or more of respondents choosing “somewhat important” or “extremely important” and negative consensus was defined as 80% or more of respondents choosing “completely unimportant” or “somewhat unimportant”. Additionally, Cronbach’s alpha ($\alpha$) was calculated to measure the group’s consistency for each round:

$$\alpha = \frac{k}{k-1} \left(1 - \frac{\sum_{i=1}^{k} \sigma_i^2}{\sigma_T^2}\right)$$

Equation 1

where $k$ is the number of panellists, $\sigma_i^2$ are the variances of each panellist’s responses and $\sigma_T^2$ is the variance of the sum of responses for each individual panellist. Cronbach’s alpha provides an estimation of the reliability of the sum of the panellists’ responses (e.g., [7]) and it works because the variance of the sum of a group of independent variables is the sum of their variances [19]. It is generally accepted that alpha values greater than 0.7 are adequate for research purposes while values greater than 0.9 are required for clinical applications [19, 20].

2.2 Results

2.2.1 Panellists

Thirty-three IPC experts agreed to participate in the Delphi survey; however, only thirty participants responded to the first round. In general, the respondents were quite experienced and represented a range of IPC perspectives: sixty-three percent (63%) of respondents reported that they have been practicing IPC for over ten years; forty-three percent (43%) were involved in clinical practice, eighty-three percent (83%) in education, fifty percent (50%) in policy-making and fifty-three percent (53%) in research. Twenty-five participants responded to the second round of the survey (83% retention) and twenty-three responded to the third round (76.7% overall retention).
2.2.2 Evaluation Rounds

Members of the advisory committee reviewed checklist and global rating items for face validity before they were distributed to the Delphi panel. The first round consisted of twenty-seven checklist items and three global rating items. Eight checklist items and all global rating items were accepted in the first round but there were also suggestions and comments that required revision of items or additional items in the second round. Most significantly, panellists requested a separate checklist section to assess hand hygiene, three new global rating items and a pass/fail assessment item. The second round presented all the accepted, new and revised items. The third round presented the accepted and unaccepted checklist items as well as solicited comments about the global rating anchor descriptions.

Overall, the majority of the items put forth achieved positive consensus and no items achieved negative consensus, indicating that the process for initial item generation was generally successful. The global rating items generated the most ‘discussion’ because many panellists did not understand the utility of subjective rating items on a five-point scale. Many comments in the first round were related to seeking clarifications for the holistic, qualitative terms used in the GRS anchor descriptions, e.g., ‘mostly’, as well as expressing concern that there were no intermediate levels of performance at level 2 or level 4 between the anchor descriptions given for levels 1, 3 and 5. Panellists were also concerned about the consistency of results that would result from this type of evaluation as well as the quality and usefulness of feedback that users would receive. From the comments, three new global rating items (4, 5 and 6) were devised and put forward to the group in round 2. Although all these items were accepted, there were still a number of suggestions at the end of round 3 about the wording of the anchor descriptions. A summary of the final assessment tool is shown in Figure 1 and the full PPE Skills Assessment Tool is available in Appendix 1.
Cronbach’s alpha calculations were done to determine the group’s consistency. Alpha values across all three rounds ranged from 0.82 to 0.99 and all values are outlined in Table 1. There is no alpha value for Hand Hygiene in round 1 or Global Rating in round 3 because Hand Hygiene was introduced in round 2 and all Global Rating items had achieved consensus at the end of round 2.

Table 1: Cronbach’s alpha for each section and iteration of the Delphi survey.

<table>
<thead>
<tr>
<th>Round</th>
<th>Hand Hygiene</th>
<th>Donning</th>
<th>Doffing</th>
<th>Global Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round 1</td>
<td>N/A</td>
<td>0.88</td>
<td>0.82</td>
<td>0.94</td>
</tr>
<tr>
<td>Round 2</td>
<td>0.89</td>
<td>0.98</td>
<td>0.96</td>
<td>0.93</td>
</tr>
<tr>
<td>Round 3</td>
<td>0.96</td>
<td>0.99</td>
<td>0.97</td>
<td>N/A</td>
</tr>
</tbody>
</table>

3 Tool Validation

3.1 Methodology

The tool was subjected to testing to investigate its ability to detect different levels of performance (due to experience or practice) as well as produce similar results between
independent raters for the same performance (inter-rater reliability). Twenty-nine individuals with no or minimal experience in healthcare delivery and eleven individuals with moderate to extensive experience using PPE in healthcare participated. The individuals with no experience (newly-trained group) underwent a training session which was comprised of the Ontario Ministry of Health and Long-term Care Core Competency Education modules in Hand Hygiene and Routine Practices (maximum forty minutes) [17]. Novice participants were trained in order to better simulate the skill levels of PPE users who might actually be evaluated using the assessment tool. Subsequent to training, newly-trained participants responded to a mock clinical scenario (Baseline test) while their performance was videotaped: participants were asked to select and demonstrate use of PPE for the clinical activities described while employing a think-aloud strategy to explain their choices and actions. They then received an additional twenty minutes to obtain feedback, review the material and/or practice using the PPE. A second mock scenario (Immediate Transfer test) was then administered and participants returned one week later for a Delayed Transfer test.

Experienced participants included medical residents, registered nurses, nursing students and advanced occupational therapy students. They had the option to review the training modules (maximum forty minutes) before completing the Baseline test but did not participate in the review/practice session, Immediate or Delayed Transfer test. Two experts (infection prevention and control practitioners), blinded to the users’ level of experience, used the PPE Skills Assessment Tool to assess video recordings of the demonstrations.

3.2 Results

Before the Baseline test, users from the newly-trained group used the tutorial for 38 ± 1 min (mean ± SE) while experienced users used it for 13 ± 3 min. A reliability analysis was performed with the ratings of both expert observers using all the scores of the newly-trained and experienced users for the Baseline test. This analysis revealed that the raters’ scores were positively and significantly correlated (Pearson’s r = 0.92, p < 0.01). As such, average inter-rater scores were used for all subsequent analyses. Baseline scores for newly-trained and experienced users, on each section of the assessment tool, were subjected to one-way ANOVAs using level of experience (experienced/newly trained) as a between-subjects variable. This compared the performance of the two groups, as recorded on each section of the PPE Skills Assessment Tool –
Hand Hygiene, Donning, Doffing and Global Rating Scale. The hand hygiene score of one experienced user was omitted because the user misinterpreted the instructions and only stated that she would perform hand hygiene instead of actually performing it. The analysis revealed that experienced users were scored significantly higher than newly-trained users only for the global rating portion of the assessment tool, $F(1, 38) = 6.822, p = 0.013$. The results are summarized in Figure 2.

![Figure 2: Mean scores (and standard error bars) for newly-trained and experienced users at Baseline testing. Asterisk (*) indicates a statistically significant difference between groups.](image-url)

Repeated measures ANOVAs were performed with time of test (Baseline/Immediate Transfer/Delayed Transfer) as a within-subject variable, for the newly-trained users’ Hand Hygiene and GRS scores (Figure 3). Only the scores from the Hand Hygiene and GRS sections were compared because, unlike the Donning and Doffing sections, they are not directly related to the specific scenario being used for testing. The scenario used for Immediate and Delayed Transfer tests was different from that used for the Baseline test, which required fewer PPE items and would inevitably produce lower scores for donning and doffing. This analysis revealed that
for the Hand Hygiene checklist, there were no significant differences in scores among the three tests (p > 0.05). For the GRS, Mauchly’s test indicated that the assumption of sphericity had been violated (chi-square = 7.044, p = 0.03); therefore, degrees of freedom were corrected using Huynh-Feldt estimates of sphericity (epsilon > 0.75). The results indicate that the scores of the three tests were significantly different, F(2, 19) = 5.199, p = 0.016. Post hoc tests revealed that Baseline scores were significantly lower than Delayed transfer scores (p = 0.006) but there was no difference between Immediate and Delayed Transfer scores.

Figure 3: Mean scores (and standard error bars) for newly-trained users at three test points. Asterisk (*) indicates a statistically significant difference between tests.

The GRS scores of the newly-trained users at Delayed Transfer were then compared to the GRS scores of the experienced users at Baseline using an independent t-test (equal variances not assumed). This analysis revealed that there was no significant difference between the scores of these groups, t = 1.885(13.607), p = 0.081.
4 Discussion

Using the Delphi consensus technique, the opinions of experts were utilized to determine items that are relevant for the evaluation of PPE users who are required to select as well as don and doff PPE for clinical practice. These items included both technique-specific checklist items (scored dichotomously) as well as holistic global rating items (scored with a five-point Likert scale) and were subsequently organized into a modular assessment tool that can be modified to suit the context of the educational/assessment program (see Appendix 1).

The Delphi technique allowed the collection of opinions from a sample of professionals involved in IPC from across Canada while maintaining anonymity of the panellists. The retention of participants throughout the process was moderate and the internal consistency of the group was also moderate to high. In the first round, Cronbach’s alpha values varied from 0.82 to 0.94, well above the criteria for research contexts. For the second and third rounds, all alpha values were greater than or equal to 0.93. This suggests that our panellists responded similarly and consistently to items in each section.

Validation testing suggests that multiple independent raters can use the PPE Skills Assessment Tool to achieve similar scores. Additionally, the GRS section of the tool is valuable for distinguishing between the performances of PPE users with different levels of experience. Although the other sections of the tool were not able to elucidate different skill levels, the result is still remarkable for two main reasons. First, the experienced users were not IPC experts and there was a range of experiences within this group with respect to the training received for acquisition and the current frequency of opportunities for practice of the skill. Second, users in the newly-trained group were not novices since they had just prior received training. As mentioned above, newly-trained users as opposed to true novices were used to simulate a more clinically relevant and practical testing situation. Third, some newly-trained users had some prior experience with using PPE, but as with the experienced group, there was a range of experiences with respect to the format and detail of training. As such, the difference in skill between the two groups was not as great as it could have been and the gap in skill level was further diminished since the Baseline test was performed immediately after the newly-trained users completed the tutorial for skill acquisition and the scenario used for Baseline testing was fairly simple, requiring only two items of PPE. It is possible that newly-trained users are better able to recall
technique-specific information immediately after acquisition and so are indistinguishable from experienced users. Appropriate performance as judged by holistic or global indicators, on the other hand, requires practice and experience. That the GRS was able to detect differences, even without users with polar opposite skill levels (i.e., experts and novices), speaks to the clinical relevance and utility of the GRS in realistic testing situations. The GRS may also provide more impactful performance data with respect to higher-order, decision-making skills that is more useful to both trainers and trainees in providing feedback to help users deepen their understanding of infection control procedures and principles.

The sensitivity of the tool was inferred from the presence of differences in performance of newly-trained users for the Baseline, Immediate Transfer and Delayed Transfer tests. However, there is a confounding factor in this analysis – the scenario used for each testing session. The scenario was changed between Baseline and Immediate Transfer for two reasons. The first is that the time between the first two tests was only twenty minutes and participants were given feedback on their performance after the first test. If the same scenario was used for the second test, it is highly likely that participants would respond based only on recollection of their previous performance and feedback. This would not accurately assess the effect of practice on performance. Secondly, use of PPE is a procedural skill and part of the skill set is the ability to assess a situation and respond appropriately. As such, a user’s performance should be assessable regardless of the scenario used. In order to compare the performance of users on two different scenarios, only the Hand Hygiene and GRS sections of the assessment were compared since the number of PPE items required for a scenario does not contribute directly to the score received. Similar to the between-group analysis, there were significant differences in score for the GRS but not the Hand Hygiene checklist. Newly-trained PPE users received higher scores at Delayed Transfer compared to Baseline, suggesting that users benefited from practice and contrary to our hypothesis, performance did not decrease at Delayed Transfer. The improvement in performance after Baseline testing was likely the result of the practice and feedback received subsequent to Baseline testing. Furthermore, a comparison of the GRS scores of experienced users at Baseline and that of newly-trained users at Delayed Transfer show that these groups were not different. This implies that the newly-trained users were able to improve their performance to the level of the experienced users after the practice and feedback received after Baseline testing.
5 Conclusion

The Delphi technique was employed to obtain consensus among professionals involved with IPC in healthcare. These consensual items were utilized to formulate a PPE Skills Assessment Tool consisting of technique-based checklist items as well as holistic global rating items. Validation testing indicated that the tool, the GRS in particular, is useful for distinguishing the performance of newly-trained and experienced users as well as detecting improvement in performance of newly-trained users after practice and a retention period. It is likely that newly-trained users were not distinguishable from experienced users based on checklist items because these items are easier to recall and master immediately following skill acquisition. In contrast, newly-trained users were able to achieve the experienced users’ level of holistic performance one week after skill acquisition after they were able to consolidate the skills acquired with practice and feedback received subsequent to Baseline testing. Further validation testing with other clinical scenarios and perhaps IPC experts (as opposed to experienced users) may serve to validate the utility of the checklist sections or confirm the present findings that the GRS is sufficient and efficient for assessment of PPE skills.
Chapter 3
Development of an Interactive Computer-Based Simulation for Practicing Healthcare Personal Protective Equipment Skills

**Target Journal:** The Association for Computing Machinery Special Interest Group on Computer Human Interaction 2011 Conference Proceedings

**Keywords:** Interactive simulation, clinical skill, infection control, practice, learning

1 Background

1.1 Computer-Based Instruction in Medical Education

In response to the demand for less expensive and more accessible alternatives or supplements to medical education, computer-based instruction has emerged as a viable option. Computer-based instruction has been used for teaching and assessing various aspects of healthcare professional education over the past three decades. Forms of computer-based instruction include the translation of textbooks to electronic format, tutorials for specific subjects, quizzing software, simulations and study guides [21]. Computer-based instruction has the potential to increase accessibility to the learning experience (especially, if it is available online), as well as reduce the scheduling and space demands for other forms of instruction such as lectures or physical simulations.

Healthcare practitioners in the field of infection prevention and control (IPC) experimented with the use of computers for teaching infection control skills as early as 1984 [22]. The authors describe the first in a series of infection control computer learning games developed to teach nurses proper hand washing skills. They purport that the game presents the dry and factual material in an exciting and stimulating way that should enhance learning as well as the learning experience. Learning was to be measured as performance on a multiple choice quiz presented on the computer screen while the learning experience was evaluated by a separate questionnaire presented to students and faculty members. The authors emphasize that this method of instruction is made successful through primary and secondary reinforcement mechanisms. The primary mechanisms are positive reinforcement for correct responses and explanatory
information for negative responses. The secondary mechanisms include the use of graphics, sound and motion to maintain motivation and enhance the content of the game. Mooney and Bligh (1998) used high-quality graphics, multimedia techniques and education principles to develop the CD-ROM based Cyber Interactive Self-Testing (CyberIST©) game designed for ‘junior doctors’ and medical students. CyberIST© operates in two configurations that allow the learner to either answer questions at his/her own pace (revision) or compete against the computer or other students (competition). There are different question types from a variety of subject areas that allow users to test different aspects of knowledge and understanding. In addition to this, the Ontario Ministry of Health and Long-term Care (MOHLTC) has developed a series of online infection control educational modules intended to instruct users about hand hygiene, routes of transmission as well as the use of personal protective equipment. It involves a combination of short quizzes, videos and instructive text. Users are also required to complete a pre- and post-test to review aspects of knowledge and understanding [17, 23].

1.2 Computer-Based Simulation

Despite the creativity of the above mentioned projects in computer-based instruction, one must question the degree to which knowledge and skill transfer can be expected to occur for skills that require experiential or physical practice for acquisition and retention. These may be examples of electronic learning media that simply comprise a reproduction of traditional classroom content electronically; which in no way implies that learning and subsequent performance will be improved [24]. Proponents of electronic learning argue that tangible gains in learning and performance will be achieved when electronic media are utilized to create experiential learning spaces [24]. Some investigators have found that the use of computer-based simulation may improve learning of clinical tasks by creating such learning spaces. A computerized advanced cardiac life support simulator was used to show that studying with the simulator improved performance on a mock resuscitation examination as compared to textbook-only studying [25]. It has also been demonstrated that medical residents who trained on a computer-based anaesthesia simulator performed better on mannequin-based simulated anaesthetic emergencies than those who trained using a hand-out [26]. An interactive computer-based simulation for training medical students and residents to perform knee replacement surgery was shown to result in students making fewer errors and performing the procedure in less time on bone models with real instruments [27]. A virtual simulation of care for a patient in isolation for an antibiotic-resistant
microorganism has also been developed [28]. While a published report of knowledge and skills transfer is not yet available for this program, pilot studies have received positive feedback – eighty-seven percent reported that the program helped to connect IPC theory to clinical practice and eighty-three percent enjoyed using the program. The aforementioned studies testify that there is some evidence of the utility of computer-based simulations in medical education. However, there are few examples in the area of infection control and many of the reports are incomplete with regards to details of the instructional program or effectiveness of knowledge and skills transfer and retention.

1.3 Infection Prevention and Control Instruction

Important IPC measures in healthcare include hand hygiene, nurse to patient ratio, bed space/accommodations, maintenance of equipment and use of personal protective equipment (PPE), which include items such as gloves, gowns, masks and goggles. IPC instruction usually involves some combination of lecture-delivered material and demonstrations. While it is assumed that these methods are sufficient for delivering the required skills, it is clear from the statistics of healthcare-associated infections [3] that gaps remain in knowledge and practice. These educational paradigms present a challenge for acquiring the complex procedural skills involved in IPC, in particular, hand hygiene and use of PPE. These skills, which have both cognitive and motor performance elements, require practice for effective acquisition and maintenance of proficiency [29]. Additionally, there may be a lengthy interval between initial acquisition and clinical use of the skill, which allows for substantial skill decay [30]. The effects of inadequate proficiency are especially dangerous in emergency situations where there are increased chances of transmitting or contracting infections and there may be insufficient time or resources to train or retrain staff to use the required equipment.

There have been efforts to diversify the format of training/refresher programs available as well as to increase the effectiveness and accessibility of training programs as healthcare workers (HCWs) are often challenged for time. For example, the Southwestern Ontario Regional Infection Control Network (Ontario, Canada) developed a video titled “The Grand Prix of PPE - What to Wear in Long-Term Care” that takes a humorous approach to teaching the basics of using PPE [31]. The goal is that humour will enliven the learning material and enhance knowledge transfer and retention. One must note that, realistically, this video could only be one
of many resources in an educational program as it does not involve physical practice, which is critical for effective learning of these skills. In comparison, the Ottawa Hospital (Ontario, Canada) launched a revamped PPE training program that included verbal explanations, demonstrations and return demonstrations, videos, individual feedback and positive reinforcement [13]. The authors measured the success of the program by measuring the short-term retention of information (80% of return demonstrations were performed correctly) and the self-reported utility of the program (99% reported the program helpful to their practice). However, a program such as this is time and labour intensive, especially if undertaken by a large healthcare facility for all HCWs.

The development of a simulation, Cover Up, was proposed, to provide a medium for practice of PPE skills in healthcare, particularly for routine practices. Its content was determined by the existing guidelines for the use of the PPE, especially as determined by a previous Delphi survey of infection prevention and control experts across Canada (Williams et al., manuscript in preparation) that sought to identify the relevant performance indicators for a PPE user. The use of PPE, as a skill, was analyzed to assess its task organization and complexity. Additionally, key principles of skill learning and human-computer interaction (HCI) were applied to guide the underlying design and operation of the simulation.

2 Cover Up

Cover Up is a two-dimensional interactive computer-based simulation where HCWs must follow routine precautions for using personal protective equipment (PPE) in the context of performing a number of clinical tasks. The user progresses through three levels (called floors) of simulation to practice handling, selection and sequencing of PPE. The simulation architecture is summarized in Figure 4 while annotated screenshots from each floor are available in Appendix 2. The simulation can be accessed online at [www.ot.utoronto.ca/coverup](http://www.ot.utoronto.ca/coverup).

Cover Up was programmed as a Java applet, which runs inside an Internet browser and is compatible with many different computer operating systems. The simulation requires < 1.2 MB, which allows quick loading even with slower internet connections. It was compiled with Java 6 Standard Edition (Sun Microsystems) and requires that Java Runtime is installed on the user’s computer (Java Runtime is pre-installed on most computers and can be easily downloaded from [www.java.com](http://www.java.com)).
Figure 4: Overall architecture of the simulation Cover Up showing the flow from the main menu through each level (floor) of the simulation. Image numbers are cross-referenced to the annotated screenshots in Appendix 2.

The content of the simulation was designed specifically for this purpose and evolved with the design of the interface and mechanics of the simulation. The framework was built upon the
identification of three major tasks involving PPE use (selection, handling, and sequencing). This led to the population of three learning levels in the simulation. Scenarios based on clinical tasks were the basis of two of the simulation’s three learning levels and were intended to firmly ground the user’s learning in practical situations that would enhance learning and engagement. Since the simulation is geared primarily toward junior trainees, they covered a wide range of clinical tasks in various fields (e.g., nursing, medicine, occupational therapy) and required minimal field-specific knowledge. Information from a variety of sources including online resources, return demonstrations from a local hospital, and provincial and federal guidelines on infection control were consolidated to develop the scenarios. They consisted of brief statements describing a patient’s condition and a clinical task to be performed. For each scenario, an answer key (correct PPE selection and sequencing procedure) and difficulty level (easy, medium or hard) was outlined. Once a preliminary list of scenarios with corresponding answer keys was developed, the scenarios were reviewed iteratively by several health care professionals in the fields of nursing and occupational therapy for accuracy and content validity. This was done to achieve a reasonable level of difficulty for newly-trained PPE users from various healthcare and allied healthcare fields as well as consistency in the level of clinical relevance that is required for an interactive simulation.

The designer and programmer also developed the simulation’s mechanics, with respect to scoring and feedback, iteratively. The final system includes both positive and negative scoring with the goal of making the simulation both realistic and challenging for users (e.g., one opportunity for completing each scenario) but would not result quickly in frustration and encouraged continuous and repeated use of the simulation (e.g., knowledge of results and numerical scores provided).

2.1 Graphics and User Interface

The graphics were hand-drawn, scanned then manually traced and coloured with digital painting software Photoshop 6 and GIMP 2.6. The file format used was 24-bit portable network graphics (.png), which provides a reasonable compromise of visual quality and file size. The applet’s resolution is 640 x 480 pixels but a screen resolution of 1024 x 768 pixels or above is recommended.
All interactions with the simulation – selecting objects, controlling the avatar on the first levels and interacting with background objects – require a traditional mouse and keyboard. All in-simulation text is displayed at 14pt font size and large, obvious buttons change colour when the user hovers with the computer’s mouse. Users are also able to interact with background objects on the second and third levels – the hand sanitizer and sink – highlighted by a visual pulsating aura that appears when the mouse moves over the object. There is a large help button at the top-right corner of most game screens that displays hints and other information relevant to the current task.

2.2 Programming and Applet-Server Communication

The simulation was designed modularly to improve efficiency, ease of revisions and debugging. The simulation data (e.g., donning and doffing steps for PPE, scenarios, introductory text, and help slides) are mostly located in text files that are easily edited without modifying the Java application. On the first floor, one of approximately twenty different hallways maps is selected randomly each time a new game is started. The locations of the PPE stations are fixed for each map but the specific PPE used at each station is randomized. Scenarios for the second and third floors are organized into rosters, one of which is chosen randomly for each new session. Seven cases are then chosen from this roster for the current session.

The simulation is available to both guests and pre-registered users (identified by username and password). Users’ account information and session logs are stored in a server-side MySQL database. Previous users can start the simulation from any of the floors that have been previously completed and so bypass content that they have mastered. The applet itself does not store any database or user account information but instead transmits this information to a server-side PHP script that authenticates users and saves logs to the MySQL database. Administrators can access session logs and view this information through the web interface or download data to a Comma Separated Values (.csv) file, which can be opened and edited with spreadsheet software such as Microsoft Excel. High scores are also displayed (by username) on the main page so that users can get a sense of their performance in relation to others, which may encourage a healthy level of competition.
3 Design Considerations

3.1 Skill Analysis and Classification

Skill analysis is essential to identify the learners’ needs and potential barriers to the teaching/learning process. Using PPE in healthcare is a complex skill that can be classified in multiple ways. It is governed by cognitive skills, since learners must understand principles of IPC, as well as physical/motor skills for interacting with the equipment. Furthermore, it involves the use of gloves, gowns, face protection and eye protection that must each be put on and removed in specific ways, all in a particular sequence. Based on findings from the aforementioned Delphi survey, the skill was divided into three major tasks: selection, handling and sequencing. Additionally, the aspects of selection and sequencing depend on the clinical scenario presented to the learner. These characteristics classify this skill as an open, procedural skill and served to determine the optimal practice parameters.

3.2 Principles of Skill Learning

The challenge point framework states that learning, as inferred through performance, is related to the amount information available, which depends on the functional difficulty of the task to be learned [32]. In order to constantly challenge the learner by gradually providing more information, the practice conditions should be altered to increase the functional difficulty of the task. It has also been shown that task complexity (number of task segments) and task organization (interrelationships between task segments) interact to affect the efficiency of training methods [33]. The use of PPE is readily divided into multiple segments that are quite independent of each other, classifying this task as a low organization, high complexity task. Based on the Naylor Interaction Hypothesis [33], part-task training, which breaks the task into several subtasks, should be more efficient for practice of PPE skills. Combining the principles of the challenge point framework and Naylor Interaction Hypothesis, the simulation was designed to allow practice conditions that gradually present more information to challenge the learner and allow independent practice of subtasks.

The challenge point framework also states that the functional difficulty of the task is determined in part by the learner’s skill level, which may and should change as practice progresses [32]. The simulation indirectly assesses the user’s progress by controlling advancement through the floors.
based on performance. Furthermore, the learner is allowed to bypass floors containing subtasks that s/he have already mastered and spend more time practicing more difficult subtasks.

Feedback refers to information received about the relationship between the actual and intended performance on a given task and has been described as one of the most important variables for facilitating skill learning [34]. It may include information that is inherent in the task performance (e.g., whether or not the ball went through the net after a basketball throw) or information provided by an external source (e.g., advice from a coach after a basketball throw). Some aspects of PPE performance may lend itself to inherent feedback. For example, users can clearly see when they have properly donned gloves; however, they cannot see whether or not agents of infection have contaminated an otherwise clean surface.

The type of feedback may also vary in terms of the kind of information that is relayed to the performer. Knowledge of results consists of goal-oriented information about the performance of the task while knowledge of performance consists of process-oriented information about performance [34]. For the skill addressed here, knowledge of results might include whether the learner was fully prepared for a scenario or whether the user would have contaminated their hands by handling a piece of equipment in a certain way. Knowledge of performance might include details of a particular error that was made in handling a piece of equipment. Since this task includes both cognitive and physical elements, both types of feedback were included in the simulation.

Motivation has also been identified in the literature as a key component to effective learning. More motivated learners will devote greater effort to the task, be more conscientious during learning sessions and practice for longer periods of time [34]. Consequently, the simulation attempted to provide the learner with an engaging learning environment that promotes concentration and commitment to the task. Smart games or educational video games have been identified as a medium for providing potentially stimulating and engaging experiential learning environments [24, 35]. As such, elements of video game design such as colourful high-quality graphics and rewarding success with points were incorporated into the design.
3.3 Concepts in Human-Computer Interaction

It is essential to consider the impact of human-computer interaction (HCI) concepts on the processes of learning when developing a computer application that is geared towards supporting education. Novice application users and novice or newly-trained learners have the double challenge of becoming familiar with the software as well as learning and/or practicing the knowledge and/or skills that are the basis of the application. In fact, researchers have noted that some HCI design goals must be adapted to pedagogy and learning theories when applied to technology that aims to support learning. This is because, in some cases, enhanced interaction (e.g., efficient task execution) precludes active and essential learning processes [36, 37].

In order to minimize the short-term memory that users would need to devote to learning how to use the simulation, the design included principles of usability. Some important goals included learnability and use efficiency [36, 38]. These were achieved in the design through various methods. The number of required control devices was minimized (only keyboard arrow keys and a mouse) and displays were kept relatively simple and consistent from one screen to another. Functions (in the form of actions buttons and menu items) were made clearly visible through labeling and iconography to enhance visibility and increase the meaningfulness of symbolic representations [38, 39]. Users were also provided with intrinsic visual feedback about actions that were performed to prevent confusion and enhance cognitive authenticity of the application [38, 39]. Graphical elements (toolbars, action buttons, help function) and fundamental tasks and interactions were kept consistent throughout the application to enhance learnability and reduce the cognitive load (and errors) related to use of the application [38, 39]. A balance was struck between the usability of the application and authenticity of the interactions (physical control required to perform tasks) to attain reasonable navigational fidelity [39].

It should be noted that user experience and usability are interdependent since usability affects the quality of the user experience and aspects of user experience impact users’ perceptions of the system’s usability [38]. In addition to striving for an aesthetically pleasing interface, the simulation was designed with the theme of a healthcare facility to encourage user engagement and motivation (also identified in the skill learning literature) in a relevant learning space.
4 Evaluation of the Simulation

Twenty-four pilot users received training for using PPE for routine practices by using the MOHLTC Core Competency Education modules (online tutorial). After a 10-minute break, they were allowed up to twenty minutes for practice but were assigned to one of two groups. One group was allowed to review the online tutorial (control group) while the second group was allowed to use the simulation Cover Up (experimental group). One week later, both groups completed a satisfaction survey (Appendix 3) about the learning tool(s) that they had used.

4.1 Subjective Evaluation

The survey consisted of ten statements and asked users to rate their agreement with each statement on a scale from 1 (strongly disagree) to 5 (strongly agree). The same survey questions were applied to both the online tutorial and Cover Up. The control group completed the survey for the online tutorial only while the experimental group completed a survey for each of the online tutorial and simulation. The responses of the experimental group for the online tutorial and the simulation Cover Up are summarized in Table 2.

A one-way ANOVA with group (Control/Experimental) as a between-subject variable revealed that there were no differences in agreement between groups, on any statement, for the survey responses about the online tutorial. However, a one-way, repeated measures ANOVA with learning tool (Tutorial/Simulation) as a within-subject variable was performed on the survey responses of the experimental group. This analysis revealed differences between responses about the online tutorial and the simulation. Specifically, there was significantly more agreement on statement two for the online tutorial, $F(1, 11) = 5.863, p = 0.034$. Statement two read, “There was enough information provided by the learning tool at the beginning to provide direction and encouragement.” These results suggest that the simulation is comparable to the online tutorial in terms of overall utility as a learning and practice tool as well as quality of feedback and motivation. However, there are several possible explanations for the difference in agreement on statement two. The first is that the simulation did not provide enough information to provide direction and encouragement. Second, if this information was actually available, the simulation did not encourage users to pay attention to it. Third, users may have misinterpreted the intention of the simulation. That is, their expectations may have been for a program similar to the MOHLTC modules, that is, quite instructive, as opposed to the practice-oriented nature of the
simulation which does not provide any direct knowledge or teaching regarding routine practices or IPC principles. Fourth, in spite of users’ possible misconceptions about the purpose of the simulation, novice users may inherently require more instructional and directional information for effective practice of skills at this stage of learning.

Table 2: Summary of survey responses from the experimental group showing mean ratings of agreement. Asterisk (*) and bold, italicized font indicates a statistically significant difference in rating between the tutorial and simulation.

<table>
<thead>
<tr>
<th>#</th>
<th>Statement</th>
<th>Tutorial</th>
<th>Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I clearly understood the purpose and objectives of the learning tool.</td>
<td>4.5</td>
<td>4.3</td>
</tr>
<tr>
<td>2</td>
<td>There was enough information provided by the learning tool at the beginning to provide direction and encouragement. *</td>
<td>4.3</td>
<td>3.3</td>
</tr>
<tr>
<td>3</td>
<td>The learning tool motivated me to learn.</td>
<td>3.7</td>
<td>4.0</td>
</tr>
<tr>
<td>4</td>
<td>Real life factors, situations, and variables were built into the learning tool scenarios.</td>
<td>3.5</td>
<td>4.1</td>
</tr>
<tr>
<td>5</td>
<td>The learning tool provided clear and adequate information for me to complete the tasks/answer and question/problem-solve the situations.</td>
<td>3.8</td>
<td>3.3</td>
</tr>
<tr>
<td>6</td>
<td>The learning tool was appropriate for my specific level of knowledge and skills.</td>
<td>3.9</td>
<td>3.8</td>
</tr>
<tr>
<td>7</td>
<td>Feedback provided by the learning tool was constructive.</td>
<td>3.4</td>
<td>3.2</td>
</tr>
<tr>
<td>8</td>
<td>The learning tool provided feedback in a timely manner</td>
<td>4.2</td>
<td>4.0</td>
</tr>
<tr>
<td>9</td>
<td>I am confident that I am developing the skills and obtaining the knowledge presented to me in this learning tool.</td>
<td>3.8</td>
<td>3.8</td>
</tr>
<tr>
<td>10</td>
<td>I would recommend this learning tool to others who need to learn this skill.</td>
<td>3.8</td>
<td>3.8</td>
</tr>
</tbody>
</table>

4.2 Pilot Data

A one-way ANOVA on practice time with group (Control/Experimental) as a between-subject variable revealed that after initially training with the MOHLTC modules, experimental group users practiced for a significantly longer period of time with the simulation (average of 20 min – the maximum time allowed) as compared to the control group users who had access to the MOHLTC online tutorials (average 6 min), $F(1, 22) = 225.094, p < 0.001$. This suggests that
users are more interested and engaged in practice when presented with the simulation. However, this result may be confounded by the novelty of the simulation, that is, users could have been more engaged simply because the simulation was new.

5 Comments

The purpose of this study was to develop an interactive simulation that would be beneficial for practicing PPE skills in healthcare. The simulation materialized as a two-dimensional Java application that allows users to practice PPE skills in stages: handling PPE then selecting and sequencing PPE in response to clinical scenarios, and finally, performing all three aspects of the task for clinical scenarios. The design of the application took into consideration principles in skill learning such as the need for the feedback, motivation and appropriate practice conditions. Human-computer interaction literature also required consideration of the application’s inherent usability, user experience and design principles such as a visibility and consistency. Furthermore, the importance of the learning process within the context of HCI was highlighted, as many HCI principles could not be directly applied to the learning technology but instead modified to support learning. While the developed application was not designed to evaluate users’ pre-existing knowledge and then simulate appropriately matched material, the design did incorporate the concept of part-task training and the challenge point framework (from skill learning literature) that serve to align the needs of the users with the information and challenges presented by the simulation. Design principles from different fields related to the use of feedback also dictated that both visual feedback (e.g., PPE appearing on the avatar, action checklist) and feedback in the forms of knowledge of performance (items of PPE missed) and knowledge of results (points lost/gained) were incorporated into the design. The learner satisfaction survey results indicated the simulation was comparable to the established MOHLTC Core Competency Education modules with respect to learner satisfaction. However, the survey also highlighted that some users felt the amount of information provided by the simulation was insufficient to provide direction and encouragement. Pilot data indicate that newly-trained users spent significantly more time practicing if they used the simulation as opposed to repeating the MOHLTC tutorials.

It is clear that the application has several inherent limitations to its effectiveness as a tool for learning and practice. First, the limited interactivity with the environment, other HCWs and patients decreased the cognitive authenticity that supports deep learning [39]. Second, users were
not able to work through the scenarios using dialogues or discussions with real or simulated peers or preceptors. Similarly, they were unable to explore the ultimate results of their actions on themselves, their colleagues or their patients. Third, related tasks, such as waste disposal, maintenance of patient environment/accommodations and practicing non-routine (i.e., additional) precautions (airborne, droplet, contact) were excluded from the simulation. This limits the utility of the application (in its current state) for widespread distribution to healthcare trainees. Fourth, the simulation was aimed at a wide cross-section of users with different backgrounds and so contained scenarios from different healthcare fields. To better support the user, future iterations should have the content revised for a specific group of healthcare professionals (e.g., nurses or occupational therapists) or have multiple repositories of scenarios and allow the users to indicate which repository they would like to use. Additionally, there could be an optional tutorial or instructional portion for less experienced users. This would also allow the scenarios to contain more detailed and contextually rich information. Last, the overall design (as independent, unrelated scenarios) does not take full advantage of the experiential learning experience that this medium can provide. It is possible that this was not an important factor for the users tested (newly-trained) but simulation of an entire ward may more effective if the simulation is to be used by more experienced healthcare trainees or professionals.
The work described above chronicles the realization of the objectives listed in Chapter 1 of this document. An assessment tool comprising checklists for hand hygiene, doffing and donning healthcare personal protective equipment (PPE) as well as a global rating scale (GRS) for holistic PPE skills performance was developed from the results of a Delphi survey of a sample of Canadian infection prevention and control experts. There were no differences in performance scores of experienced and newly-trained PPE users based on the checklist sections of the tool. However, experienced users received higher scores than newly-trained users on the GRS. Similarly, newly-trained users received higher GRS scores on an Immediate Transfer test and significantly higher scores on a one-week Delayed Transfer test, as compared to a Baseline test, which was done immediately after skill acquisition. These results suggest that for the skills involved with using PPE, a GRS may be more effective for assessing performance. Since the GRS is easier to complete (less time intensive) and provides insight into higher-level decision making skills associated with PPE use, this method of assessment may also be more efficient. However, further validation testing, with different scenarios is required to confirm these speculations. Nonetheless, the validated GRS can be easily incorporated into existing training programs and utilized by trainers to assess their trainees, provide feedback on knowledge and performance as well as infer the utility of training programs.

The results of the Delphi survey were also used to develop an interactive computer-based simulation for practice of PPE skills. The primary benefits of the simulation were time and place independence for PPE users and ideally, it would be used in conjunction with instruction in theoretical principles of infection control and some physical practice. Principles of skill learning and human-computer interaction were incorporated into the design and development to achieve a program that would engage and motivate learners to practice these skills. Learners rated the simulation comparable to a provincial web-based educational tutorial but would have liked the simulation to provide more guidance to direct learning at the outset. While further testing is required to fully assess the effectiveness of the simulation for practice and retention of PPE skills, one might speculate that the procedural nature of the skills might benefit from a more holistic simulation of a clinical environment. Nonetheless, this simulation is valuable for
providing clues about the level of interaction and fidelity that is required for effective practice of PPE skills at various levels of experience and knowledge. This is important because increased levels of interaction and fidelity are generally more expensive to produce and can be overwhelming for new learners. Further evaluation of the simulation will indicate its utility for newly-trained users and the scenarios can be easily modified for evaluation with more experienced users.
References


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Appendices

Appendix 1: The Personal Protective Equipment Skills Assessment Tool

### Hand Hygiene Checklist

Score each method of hand hygiene based on the tasks indicated: done - 1; not done or done incorrectly - 0; not applicable or not assessed - N/A.

<table>
<thead>
<tr>
<th>Method</th>
<th>Task</th>
<th>Status</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alcohol-Based Hand Rub</strong></td>
<td>ABHR is appropriate choice of hand hygiene for the situation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Remove inappropriate jewellery</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Use enough alcohol rub to thoroughly wet both hands</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spread product over all surfaces of hands (palms, between fingers, fingertips, back of hands and wrists)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rub hands for at least 15s or until product is dry</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Alcohol-Based Hand Rub Subtotal</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Soap and Water</strong></td>
<td>Remove inappropriate jewellery</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wet hands and apply soap</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lather all surfaces of hands for 15s (palms, between fingers, fingertips, back of hands and wrists)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rinse all sides of hands under running water</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dry hands with paper towels</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Turn off taps with paper towels</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Soap and Water Subtotal</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL SCORE**
## Donning Checklist

Indicate the personal protective equipment (PPE) required for the scenario then number them in the table as the user dons each item. Score the use of each item based on the tasks indicated: done - 1; not done or done incorrectly - 0; not applicable or not assessed - N/A.

PPE Required: __________________________________________

<table>
<thead>
<tr>
<th>User’s PPE sequence</th>
<th>Task</th>
<th>Status</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Hygiene #_____</td>
<td>Hand Hygiene was performed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>The choice of Hand Hygiene was appropriate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gown #_____</td>
<td>Choose correct type of gown (if available)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Put gown on with the opening at the back</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tie neck and waist ties</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mask #_____</td>
<td>Chosen mask is appropriate face protection for the situation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Place mask over the nose and mouth</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mould metal strip to nose</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Secure elastics or ties</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eye Protection #_____</td>
<td>Put on</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adjust to fit (e.g. face shield should fit over brow)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gloves #_____</td>
<td>Remove inappropriate jewellery</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Choose correct type of gloves (if available)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Choose well-fitting gloves</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Put on gloves (if gown is worn, place gloves over gown cuffs)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Subtotal

<table>
<thead>
<tr>
<th>PPE Selection Score</th>
<th>PPE Donning Sequence Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Add 5 points for each required item that was selected and subtract 5 points for each necessary item that was not selected.)</td>
<td>(No points if any sequence errors. Award 5 points for each required item/step in a perfect sequence - as listed in table.)</td>
</tr>
</tbody>
</table>

### TOTAL SCORE
**Doffing Checklist**

Score the use of each item based on the tasks indicated: done - 1; not done or done incorrectly - 0; not applicable or not assessed - N/A.

Number of *items* to be doffed: __________
Number of hand hygiene *steps* required: ____________

<table>
<thead>
<tr>
<th>User’s PPE sequence↓</th>
<th>Task</th>
<th>Status</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gloves #_____</td>
<td>Remove the first glove using glove-to-glove technique</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Remove the second glove using skin-to-skin technique, turning gloves inside out</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drop into garbage without touching bin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gown #_____</td>
<td>Unfasten the ties or Velcro and peel gown away from the neck</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Remove the gown slowly, pulling away from the body, without touching the outside or contaminating clothing</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Roll the gown into a bundle inside-out or fold dirty-to-dirty</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Discard the gown in appropriate receptacle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand Hygiene #_____</td>
<td>Hand Hygiene was performed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>The choice of Hand Hygiene was appropriate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eye Protection #_____</td>
<td>Remove goggles/visor using the earpiece/band</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lift away from the face without touching the face/eyes/nose</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Discard in the garbage/If reusable, clean and disinfect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mask #_____</td>
<td>Undo the ties or elastics without touching the front of the mask</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Holding the ties or elastics, lift mask away from the face</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Discard mask in the garbage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand Hygiene #_____</td>
<td>Hand Hygiene was performed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>The choice of Hand Hygiene was appropriate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Subtotal**

**Doffing Sequence Score**

(No points if any sequence errors. Award 5 points for each required item/step in a perfect sequence - as listed in table.)

**TOTAL SCORE**
### Personal Protective Equipment Skills Global Rating Scale

<table>
<thead>
<tr>
<th>Case and Risk Assessment</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(Critical risk assessment, understanding of the situation; appropriate selection of PPE)</td>
<td>N/A</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>All necessary PPE not chosen and severely flawed rationale offered for choices of PPE</td>
<td>Some necessary PPE chosen and partially correct rationale offered for choices of PPE</td>
<td>All necessary PPE chosen and sound rationale offered for all choices of PPE</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PPE Handling</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(Correct and careful use of PPE)</td>
<td>N/A</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Incorrect donning/doffing of PPE with critical errors</td>
<td>Mostly correct donning/doffing of PPE with few non-critical errors and/or correction of critical errors</td>
<td>Perfectly correct donning/doffing of PPE with no errors</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Flow of Operation</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(Forward planning and continuity of procedure)</td>
<td>N/A</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Demonstrated no forward planning and appeared unsure of next steps with irregular progression of actions</td>
<td>Demonstrated some forward planning and anticipation of the situation with steady progression of actions</td>
<td>Demonstrated obvious forward planning and anticipation of the situation with effortless progression of actions</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Self-Contamination</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(Avoidable/unnecessary contamination of PPE user during or after care activities)</td>
<td>N/A</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Indiscriminately contaminated self during and/or after client/patient care activities</td>
<td>Made appropriate corrections for self-contamination during and/or after client/patient care activities</td>
<td>Perfect technique employed to prevent self-contamination both during and after client/patient care activities</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Contamination of Environment</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(Contamination of environmental surfaces during or after care activities)</td>
<td>N/A</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Touched environmental surfaces inappropriately putting others at risk of transmission of microorganisms through contaminated surfaces</td>
<td>Touched environmental surfaces inappropriately but corrected errors to prevent transmission of microorganisms through contaminated surfaces</td>
<td>Did not touch environmental surfaces inappropriately, preventing risk of transmission of microorganisms through contaminated surfaces</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cross-Contamination</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(Contamination of client/patient due to contaminated PPE used between care activities and procedures)</td>
<td>N/A</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Indiscriminately caused cross-contamination of PPE and/or client/patient between care activities</td>
<td>Made appropriate corrections for cross-contamination of PPE and/or client/patient between care activities</td>
<td>Appropriate technique used throughout the procedure to prevent cross-contamination of PPE and/or client/patient between care activities</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL SCORE**
Appendix 2: Annotated screenshots from the computer-based simulation *Cover Up*

**Image #1: Main Menu**

Welcome screen of the simulation showing options for New Game, Help and Credits as well as high scores and help button (top right corner). The background is a reception desk.
Image #2: Floor 1
Introduction

Displays the instructions for the current level (floor) of the simulation with a little contextual information for user engagement.

This user has previously completed Floor 1 and has the option to bypass it and continue to Floor 2.
Image #3: Floor 1 Map with PPE Stations

Shows a bird’s eye view of the avatar and two PPE stations. The toolbar is also visible, showing the user’s score, the floor of simulation, the timer, the progress for the current floor, ‘health’ and the help button.

Avatar
Case 1 / 7

During Ms. I's therapy session, she drops a glass onto the floor. The glass breaks and she cuts her hand trying to pick up the pieces. What PPE do you need to help her?

Click the Start button to play!

Image #4: Floor 2
Presentation of Scenario
Image #5: Floor 2 User Response

The user has donned gloves and gown, as shown on the avatar and noted on the action checklist (top left). The pop-up menu for the Eyes & Face category of PPE is shown, it contains both images and labels. Also note the white aura of the hand washing station that hints at interactivity.
Image #6: Floor 3 User Response for Selection and Sequencing of PPE

Note that the background is different from that of Floor 2. The hand hygiene stations also display a white aura hinting at interactivity. The action checklist displays the user’s actions.
Image #7: Floor 3 User Response for Handling PPE

Similar to the presentation of tasks/user response screen for Floor 1. Note that the action statement changes colour (grey to blue) when the mouse hovers over it.
Image #8: Floor 3 Feedback

This is similar to the feedback given on Floor 2. It includes the points gained/lost as well as a details of which items were missed and whether or not sequencing errors were made.
Image #9: Successful Completion

The user is challenged to play again.
Appendix 3: Learner Satisfaction Survey

P#: _____________________ Learning tool: _____________________

Please assess the following statements about the learning tool stated above using the rating scale. Be truthful and describe your opinion as it really is, not what you would like it to be.

<table>
<thead>
<tr>
<th>Item</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Undecided</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I clearly understood the purpose and objectives of the learning tool.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>2. There was enough information provided by the learning tool at the beginning to provide direction and encouragement.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>3. The learning tool motivated me to learn.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>4. Real life factors, situations, and variables were built into the learning tool scenarios.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>5. The learning tool provided clear and adequate information for me to complete the tasks/answer the questions/problem-solve the situations.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>6. The learning tool was appropriate for my specific level of knowledge and skills.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>7. Feedback provided by the learning tool was constructive.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>8. The learning tool provided feedback in a timely manner.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>9. I am confident that I am developing the skills and obtaining the knowledge presented to me in this learning tool.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>10. I would recommend this learning tool to others who need to learn this skill.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

Comments: