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# Feasibility and Accessibility of Human-centered AI-based Simulation System for Improving the Occupational Safety of Clinical Workplace

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**ABSTRACT:** Medical personnel need to learn occupational safety knowledge in clinical workplaces, not only to ensure their own safety, but also to further ensure patients safety. Based on Human-centered artificial intelligence (HAI) technology, this study will provide HAI-based occupational safety training system for two training topics, Needle Stick/Sharps Injury (NSSI) prevention and appropriate Clinical Waste Management (CWM). From April 2018 to December 2021, this clinical occupational safety HAI training is used by 342 medical personnel (doctors and non-doctors). This study aims to investigate the learning performance and effectiveness including decreasing anxiety and increasing mastering level of users. This study shows that, for the first-time and feel-friendly users of this HAI training system, not only can they achieve significant learning improvement, but they can also effectively decrease their anxiety and increase their mastery level of clinical work safety knowledge and skill. In terms of learning performance and effectiveness, this study found that doctors are significantly benefited by the HAI training system in contrast to non-doctors.

**Keywords:** Clinical waste management, Needle stick sharp injury, Virtual reality

## 1. Introduction

Effective and safe patient care can only be provided if the safety of medical personnel, which includes doctor and non-doctor, are maintained. Because new medical personnel are susceptible to inappropriate Clinical Waste Management (CWM) and Needle Stick and Sharp Injuries (NSSIs). NSSI and CWM workplace safety issues are frequently discussed in hospital. Proper CWM and NSSI prevention are essential trainings for ensuring occupational safety in the clinical workplace (Gao et al., 2017; Markovic-Denic et al., 2011). In general, most of the NSSI and CWM trainings are using handouts, lectures, slides, face-to-face discussions posters, mannequin-based simulation (Ozder et al., 2013; Merandi & Williams, 2017).

Due to time and labor costs, trainings through handouts, lectures, slides, discussions, or posters are generally expensive to repeat. However, the CWM and NSSI trainings need to be available without time and space limitation so that all medical personnel can have the opportunity to repeat trainings. Therefore, hands-on learning of CWM and NSSI in HAI simulation environment may provide a solution to this challenge. Different from previous learning systems, users could gain knowledge and learn skills via human-centered learning methods by creating a personalized and self-paced tutorial (Yang, 2021), leading to a more effective medical education, especially in the occupational safety of the clinical environment.

Self-directed learning is defined as the process by which individuals guide their own learning and thereby become lifelong learners (Patterson et al., 2002; Robinson & Persky, 2020). Brockett and Hiemstra (2018) proposed that the process of self-directed learning includes four steps: planning, setting goals, selecting learning resources and re-examining the learning process, which are all completed by learners in their own learning speed. For medical personnel, self-directed learning can make them take more responsibility for the choice of learning strategies or the monitoring of self-efficacy, and then making a positive impact on their future work attitudes. Since virtual reality technology has the characteristics of instant feedback and immersive virtual environment, it is regarded as the perfect field for self-directed learning (Rozinaj et al., 2018). For this reason,

this study aims to construct a HAI-based occupational safety training system including NSSI prevention and appropriate CWM via VR technology.
A well-designed learning platform helps to build a medical education training course. Meanwhile, effectiveness including decreased anxiety and increased mastering level are important parameters to judge the quality of such learning platform. During the learning process, anxiety not only has a great impact on the learning performance of learners, but also further impairs their concentration and memory (Gibelli et al., 2019; Yang et al., 2018). For medical personnel, a high level of concentration is required to provide safe and effective patient care. Thus, this study uses two parameters, decreasing anxiety and increasing mastering level, to measure the effectiveness of HAI-based occupational safety training systems and explore following research questions:

RQ1: Exploring the impact of HAI -based training programs on the learning performance, mastery level, and user anxiety of different HAI experience groups in clinical workplace safety knowledge.

RQ2: Exploring the impact of HAI -based training programs on the learning performance, mastery level, and user anxiety of different medical personnel (doctor and non-doctor) in clinical workplace safety knowledge.

## 2. Related works

### 2.1. The occupational safety issues of clinical workplace in hospital

Needle stick and sharp injuries (NSSIs) are illustrated as percutaneous piercing wound, caused accidentally by medical or laboratory devices and appliances, such as needles, ampules, injectors, lancets, broken glass fragments, scalpels, shredded intravenous cannulation devices. Medical personnel are at high risk of needle stick or sharps injuries due to the need for repeated patient contact and various nursing behaviors in the clinical workspace of a hospital. Norsayani and Hassim (2003) further suggested that the risk of NSSI in the workplace of new medical personnel are 3 times than others. In addition, 27-40% of new medical personnel had experience NSSI during training (Wicker et al., 2008; Ghasemzadeh et al., 2015; Sharma et al., 2010). These research highlighted the necessity of NSSI education training program to improve workplace safety of new medical personnel in the hospital.

The COVID-19 pandemic has led to a surge in demand for personnel protective equipment such as gloves and masks, leading to a discussion of global waste management (Kalantary et al., 2021). With the absence of separate containers for management masks and gloves, the risk of infection from clinical waste may be substantially increased. To mitigate the risk of aerosol spread, medical personnel must consciously sort medical wastes to the correct category, which is why Kalantary et al. (2021) proposed the need for proper management of large amounts of waste in healthcare workspace. Which is to say, being able to classify the wastes and dispose them into the right collection site is a very important skill for medical personnel (Letho et al., 2021). However, a systematic review illustrated that medical personnel’s confidence and familiarity toward managing clinical waster appropriately were not as expected (Ananth et al., 2010; Abebe et al., 2017; Joshi et al., 2015; Peng et al., 2020; Yazie et al., 2019).

Both general waste and hazardous waste should be properly classified according to the source of their generation (Akkajit et al., 2020). According to previous studies, hazardous clinical waste in inappropriate clinical waste management (CWM) outnumbers the proportion of general waste (Chartier et al., 2014; Hayleeyesus & Cherinete, 2016). The reason for this may be that general waste may be polluted by the hazardous waste carelessly, creating more hazard waste. It’s evident that the wrong management process will increase the amount of hazardous waste. For example, contaminated needles and syringes have the potential to cause greater pollution throughout hazardous recycling and repackaging (Askarian & Malekmakan, 2006; Maina, 2018). Therefore, clinical waste management (CWM) training courses for new medical personnel are important.

Hospitals are the main field for disease treatment and health care, so the safety and hygienic requirements are relatively higher. Unfortunately, hospitals are also high-risk workplaces for occupational injury among various occupational fields. Therefore, the two most important workplace safety issues for new doctors in hospitals are medical waste management (CWM) and needle stick and sharps injury (NSSI) prevention education. In an attempt to ensure and maintain the safety of medical personnel, occupational safety training programs in hospital clinical workplaces are imperative.

### 2.2. The human-centered artificial intelligence is a liable design in CWM and (NSSI) prevention in our study

Artificial intelligence (AI) is a scientific principle that concentrates on creating and presenting computer algorithms that are usually designed for speeding up procedure and reducing mistakes (Hassani et al., 2020). Studies showed that, compared to conventional learning methods, AI-based learning is more likely to increased effectiveness of learning mastering level and decreased anxiety to certain fields for medical students or residents (Paranjape et al., 2019). However, in consideration of liability, trustworthy and explainability, a human-centered artificial intelligence (HAI) is now highly recommended in this field. This also applies to the training at the clinical workplace among medical personnel according to previous studies (Shneiderman, 2020).

Besides high flexibility and convenience, the virtual reality learning platform can provide 24/7 online training courses, freeing from the limitation of location, time, and personnel, achieving the purpose of training anytime, anywhere. Khunger and Kathuria (2016) also confirmed that the simulation system could help medical students learn suturing skills effectively. For medical personnel, proper clinical waste management (CWM) and prevention of NSSI are essential skills to ensure occupational safety in the clinical workplace. For these reasons, this study implemented a HAI-based occupational safety training program for CWM and NSSI units to help hospital personnel learn safety knowledge of clinical workplace.

### 2.3. Self-directed learning in medical education

Knowles (1975) defined self-directed learning as the process by which individuals learn independently without the help of others. In this learning process, learners will select learning resources and implement learning strategies according to their own learning needs, so as to learn knowledge independently, and finally evaluate their own learning performance. Brockett and Hiemstra (2018) proposed that the process of self-directed learning includes four steps: planning, setting goals, selecting learning resources and re-examining the learning process, which are all completed by learners in their own learning speed. Since learning goals are set by learners themselves in the process of self-directed learning, learners should be able to formulate clear, specific, and well-structured learning goals to reduce the challenges students face when learning knowledge independently. The learner's self-motivation and the learning strategies adopted will directly affect the success of self-directed learning. Therefore, the degree of self-directed learning will depend on the learner's attitude and ability.

With the rapid development of biomedical knowledge and medical technology systems, the knowledge acquired by medical schools can no longer meet the needs of hospitals in the medical field, which is also the main reason for the needs of Continuous Medical Education (CME) (Simpkin & Walesby, 2017). However, the learner's self-directed learning ability has a great influence on the learning outcomes of CME. For medical staff in hospitals, it is not only necessary to become lifelong learners, but also to develop self-directed learning (SDL) as a core skill (Ricotta et al., 2021). It can be seen that the importance of SDL in medical education.

In view of the importance of lifelong learning and self-directed learning skills for medical personnel to learn medical knowledge, more and more medical professional associations, such as the Medical Council of India (MCI), the World Federation of Medical Education (WFME) emphasis on developing the learning ability of medical staff through self-directed learning (Buch et al., 2021; Ricotta et al., 2021). Based on the theoretical concept of self-directed learning, Ricotta et al. (2021) were further proposed the framework of self-directed learning in medical education (SDL-ME). Self-directed learning in medical education (SDL-ME) focuses on the conceptualization of core attributes of medical professional identity. In the context of mutual social responsibility of medical staff and patients, medical knowledge skills and attitudes need to grow over time to implement appropriate medical care.

## 3. Methodology

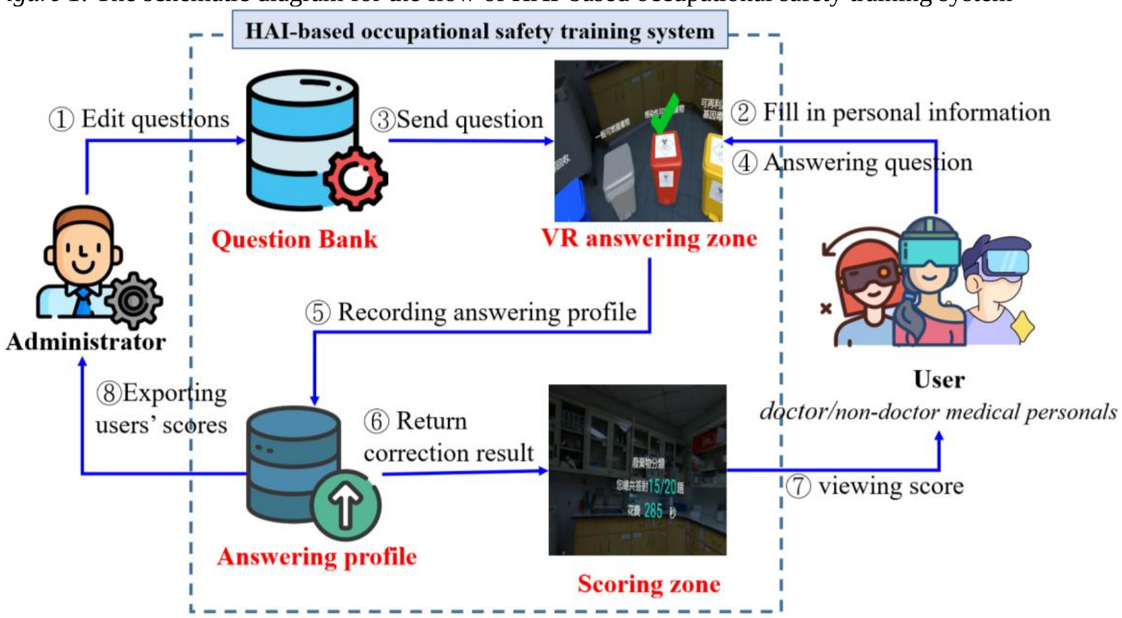
### 3.1. Participates

We conducted this prospective study in a 2800-bed 6000-staff medical center and teaching hospital in Taipei, Taiwan from April 2018 to December 2021. A total of 342 users, including doctors and non-doctors, were recruited for this study and randomly assigned to either NSSI prevention or CWM units of a HAI-based occupational safety training program. The Needle Stick and Sharps Injury prevention (NSSI) and Clinical Waste Management (CWM) units recruited 251 and 91 users, respectively.

### 3.2. HAI-based occupational safety training system

In hospitals, basic occupational training topics for clinical workplace safety mainly include needle stick/sharp injury (NSSIs) prevention and appropriate clinical waste management (CWM), usually in the form of lecture guides or demonstrations. However, due to the restriction of time and venue as well as the ever-changing schedule of trainees, it is difficult to train all medical personnel simultaneously. As a result, this study developed a HAI-based occupational safety training system, which provides a 24-hour training approach for the whole hospital and optimizes training effect based-on the real-time evaluation and feedbacks provided by the system. Figure 1 is the schematic diagram for the flow of HAI-based occupational safety training system. To elaborate, HAI-based occupational safety training system distinguished from other similar training systems by creating a precision approach, rather than a one-size-fits-all model. The precision approach provided users with personal and self-paced tutorials (Yang, 2021). It could concentrate and target on the users' weak points, leading to a safer clinical occupational environment.

*Figure 1*. The schematic diagram for the flow of HAI-based occupational safety training system

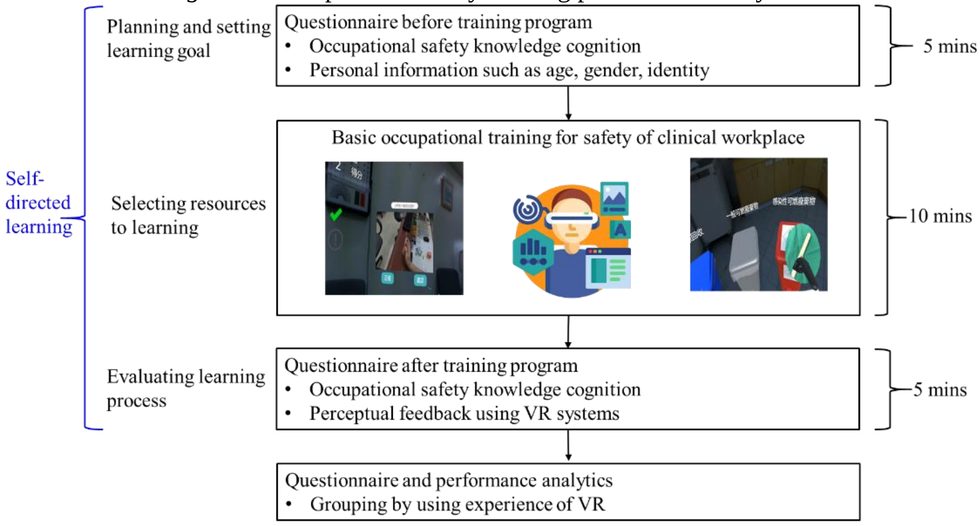



Overall, there are four components in the flow of the HAI-based occupational safety training system including question bank, VR answering zone, scoring zone, and answering profile. The user will go through the following 8 steps to partake in the training program in the HAI-based occupational safety training system. The administrator first edits 20 training questions for each of the NSSI and CWM modules in step 1. The user fills in personal information in step 2 to log in the system. Then, the question bank can start sending questions to users in step 3. The user can start the training program and answer questions in the answering zone in step 4. In order to provide training for all medical personnel, the users of this system include doctors and non-doctors. During the training process, the system transmits and stores the user's answers in the answering profile database step 5. After the user completes the training program, the task of step 6 is to extract the correction results from the answering profile database and present it in the scoring zone. Finally, in step 7, users can view the correction results on the score zone, including the number of correct answers and the time it took to answer. The main task of step 8 is to export scores of all users, so that the hospital administrator can inspect the training effect of the users.

### 3.3. Experiment design

Due to persistent, immersive, and highly interactive features of 3D virtual reality, it has gradually become a popular new online learning environment among educational courses (Lin & Lan, 2015). Therefore, we tried to integrate 3D virtuality with human-centered artificial intelligence. In order to achieve labour cost reduction of clinical safety training courses in hospital institutions, this study constructed a HAI-based occupational safety training system. Figure 2 is the HAI system occupational safety training process diagram. It is worth noticing that users need to fill out a questionnaire on occupational safety knowledge and personal information such as age, gender, and identity before HAI training in the HAI-based occupational safety training system for NSSI and CWM. The user identities in this study include doctor and non-doctor. The questionnaire first collects users' basic personal information, then explains the planning and learning goals in the HAI system occupational safety training process. Next, users need to spend about 10 minutes in the HAI system to learn the clinical workplace safety knowledge about NSSI and CWM. In order to get user's self-evaluating feedback after completing the training program, users will also be asked to fill in a feedback form including occupational safety knowledge cognition and HAI system using experience. In the end, this study will classify users by HAI using experience then analyse questionnaire results and training performance.

*Figure 2.* Occupational safety training process in HAI system




The proposed HAI-based occupational safety training program includes CWM and NSSI prevention learning topics. Hazard waste includes toxic chemicals, pharmaceuticals, medical devices waste, radioactive substances, body fluids, discarded sharps, non-sharp, and blood. Since waste can be contaminated, infectious or dangerous, it is important to place waste in the correct storage location. Therefore, for the CWM topic, users were asked to recognize 12 random clinical wastes. The HAI-based occupational safety training program is designed to allow the trainee pick up virtual items and place them in the correct bin. Needle stick and sharp injuries (NSSIs) are illustrated as percutaneous piercing wound, caused accidentally by medical or laboratory devices and appliances, such as needles, ampules, injectors, lancets, broken glass fragments, scalpels, shredded intravenous cannulation devices. NSSI is the most common cause of workplace injuries for healthcare professionals worldwide. For the NSSIs prevention topic, users will face 12 random scenarios, which including safe/unsafe behaviours with and without universal precaution for NSSIs prevention.

### 3.4. Instruments

In the HAI-based occupational safety training system, users' occupational safety knowledge cognition and learning performance will be measured through system- and self-assessments, respectively. According to occupational safety knowledge measured by the system, the proposed HAI-based occupational safety training system will calculate the number of correct answers and answering time according to the user's answering profile, so as to evaluate the user's learning performance of occupational safety knowledge. As for self-assessment occupational safety knowledge, this study will ask users to self-assess their occupational safety knowledge before and after training using a four-point Likert scale ranging from 1 (strongly disagree) to 4 (strongly agree).

This study will also ask users to self-assess their thoughts about the effectiveness of the HAI-based occupational safety training system through a four-point Likert scale. This study will also explore whether the system can decrease users' anxiety about occupational safety, and whether it can help users master the CWM and NSSIs skills. Table 1 listed the detailed description of the questionnaire used in this study for system- and self-assessments of knowledge, decreasing anxiety, increasing mastering level, HAI friendly, HAI experience. To explore the differences of the obtained training performance among different groups, this study will group users according to their HAI using experience. HAI using experience includes whether it is their first-time using HAI system and whether the HAI interface is user-friendly.

*Table 1*. Description of the questionnaire items used in this study (knowledge of system assessment, knowledge of self-assessment, anxiety, help on mastering level, HAI friendly, HAI experience)

| Scale | Variable | Description of item | Response format |
|---|---|---|---|
| Learning performance (Occupational safety knowledge) | Systematic-assessment | Number of correct answers and time to answer calculated from the answering profile after completing the training program. | Values calculated by the HAI system. |
| | Self-assessment | Occupational safety knowledge level for CWM and NSSI units. | 4: very understanding<br>3: understanding<br>2: not understanding<br>1: not understanding at all. |
| Effectiveness | Decreasing anxiety | This HAI-based occupational safety training program can effectively decrease the anxiety of occupational safety. | 4: strongly agree<br>3: agree<br>2: disagree<br>1: strongly disagree. |
| | Increasing mastering level | This HAI-based occupational safety training program can effectively help you to increase the mastery level in the CWM and NSSIs skills. | |
| HAI system experience | HAI friendly | For the presentation of occupational safety knowledge, HAI systems are better than presentations of papers or lectures. | 1: the user considers that HAI system is better than the lecture or paper presentation.<br>0: the user considers that HAI system is not better than the lecture or paper presentation. |
| | HAI experience | Are you using the HAI system for the first time? | 1: the user is using the HAI system for the first time.<br>0: the user has used the HAI system before. |

## 4. Experimental results and discussions

### 4.1. Exploring the impact of HAI-based training programs on different groups in clinical workplace safety knowledge

To explore the impact of HAI on CWM and NSSIs skills for different groups, this study divided users into groups according to two factors: whether they had the experience of using HAI or whether they felt that the HAI interface was user-friendly. The $G_Y$(Experience) and $G_N$(Experience) groups represented users with or without HAI experience, respectively. The $G_Y$(Friendly) and $G_N$(Friendly) groups represented users feeling the HAI interface user-friendly or not user-friendly. The total number of users in this experiment was 342, with 23 and 319 users in the $G_Y$(Experience) and $G_N$(Experience) groups, respectively, and 313 and 29 users in the $G_Y$(Friendly) and $G_N$(Friendly) groups, respectively. The proportion of first-time users in $G_N$(Experience) group was as high as 91.5%, and the proportion of $G_Y$(Friendly) users was as high as 91.5%. It means that most of the users had no previous experience with HAI-based training programs. The data indicated that though the majority of users felt the HAI interface user-friendly, the prevalence of usage of HAI technology in the hospital field courses remained low. However, considering the high occupational risk in the hospital field, this study aimed to create a HAI-based occupational safety training program to help users learn clinical workplace safety knowledge about NSSI and CWM.

This study used self-assessment and HAI system-based assessment to evaluate the learning performance of CWM and NSSI skills. For the self-assessment, this study conducted a four-point Likert scale pre-test and post-test on occupational safety knowledge before and after the HAI training program. For the HAI system-based assessment, this study calculated the number of correct answers in the training program as another learning performance indicator for clinical safety knowledge. Table 2 showed the independent sample *t*-test results of user self-assessment and HAI system assessment.

According to the independent sample *t*-test results of the self-assessment learning performance of the two different HAI experience groups shown in Table 2, the occupational safety knowledge pre-test of users in the $G_Y$(Experience) group was significantly higher than that of the users in the $G_N$ (Experience) group ($t$ = 2.82, $p$

< .01), but $G_Y$(Experience) and $G_N$(Experience) groups had no significant difference in the post-test of occupational safety knowledge ($t$ = -1.01, $p$ > .05). Although the pre-test of users in the $G_N$(Experience) group were lower than the users in the $G_Y$(Experience) group before training, the post-test learning performance in the $G_N$(Experience) group and the $G_Y$(Experience) group were similar. It meaned that users in the $G_N$(Experience) group benefited more from the HAI-based training program. For the independent sample $t$-test results of the HAI system-based assessment of learning performance shown in Table 2, there were no significant difference between the $G_Y$(Experienced) and $G_N$(Experienced) groups in the number of correct answers ($t$ = .12, $p$ > .05). This meaned that the average numbers of correct answers did not differ between the $G_N$(Experience) and $G_Y$(Experience) groups. From the descriptions above, the HAI-based assessment evaluation results showed that the users in the $G_Y$ (Experience) group had similar learning performance with the $G_N$ (Experience) group, but the self-assessment evaluation results showed that the users in the $G_N$ (Experience) group learned more from the HAI-based training program.

*Table 2*. The independent sample *t*-test results of learning performance for occupational safety knowledge

| | | | Self-assessment | | | | HAI system-based assessment: Correct answers | |
|---|---|---|---|---|---|---|---|---|
| | | | Pre-test | | Post-test | | | |
| Variables | Groups | # | Mean/Std. | *t* value | Mean/Std. | *t* value | Mean/Std. | *t* value |
| HAI Experience | $G_Y$(Experience) | 23 | 3.30/.65 | $2.82^{**}$ | 3.57/.79 | -1.01 | 10.57/4.48 | .12 |
| | $G_N$(Experience) | 319 | 2.80/.85 | | 3.73/.54 | | 10.66/3.74 | |
| HAI Friendly | $G_Y$(Friendly) | 313 | 2.86/.83 | -1.87 | 3.77/.49 | $-3.06^{**}$ | 10.80/3.80 | $2.32^{*}$ |
| | $G_N$(Friendly) | 29 | 2.55/.99 | | 3.24/.91 | | 9.10/3.27 | |

*Note*. # indicates the number of users in the group. $^{*}p$ < .05; $^{**}p$ < .01.

For the self-assessment learning performance results of the two different HAI friendly groups shown in Table 2, the $G_Y$(Friendly) group and the $G_N$(Friendly) group had no significant difference in the pre-test values of occupational safety knowledge ($t$ = -1.87, $p$ > .05), but there were significant differences in the post-test values (t = -3.06, $p$ < .01). The $G_Y$(Friendly) group and the $G_N$(Friendly) group had the same occupational safety knowledge before the training program, but the occupational safety knowledge of the $G_Y$(Friendly) group was significantly higher than that of the $G_N$(Friendly) group after the training program. For the results of the HAI system-based assessment learning performance shown in Table 2, there was a significant difference ($t$ = 2.32, $p$ < .05) in the number of correct answers between the $G_Y$(friendly) and $G_N$(friendly) groups. This meaned that users in the $G_Y$(friendly) group had more correct answers than users in the $G_N$(friendly) group within similar time(seconds). In conclusion, users in the $G_Y$(friendly) group had better self-assessment learning performance, while the $G_Y$(friendly) group also answered more correct answers within the same time in the HAI-system based assessment.

*Table 3.* The independent sample *t*-test results of the decreasing anxiety and increasing mastery level in the CWM and NSSIs skills

| Variable | | # | Decreasing anxiety | Increasing mastery level | Decreasing anxiety | Increasing mastery level |
|---|---|---|---|---|---|---|
| | | | Mean/Std. | *t* value | Mean/Std. | *t* value |
| HAI Experience | $G_Y$(Experience) | 23 | 2.61/.58 | .27 | 2.61/.72 | 1.07 |
| | $G_N$(Experience) | 319 | 2.65/.63 | | 2.75/.58 | |
| HAI friendly | $G_Y$(Friendly) | 313 | 2.72/.54 | $5.71^{***}$ | 2.82/.46 | $4.82^{***}$ |
| | $G_N$(Friendly) | 29 | 1.79/.86 | | 1.86/1.06 | |

*Note*. # indicates the number of users in the group. $^{***}p$ < .001.

Based on users' perception of clinical workplace safety knowledge, Table showed the independent sample $t$-test results of decreasing anxiety and increasing mastering level. After the HAI-based training program, the $G_Y$(Experience) and $G_N$ (Experience) groups had no significant difference in anxiety reduction ($t$ = .27, $p$ > .05) and mastering level ($t$ = 1.07, $p$ > .05). Nevertheless, there were significant differences between the $G_Y$(Friendly) and $G_N$(Friendly) groups in decreasing anxiety ($t$ = 5.71, $p$ < .001) and mastering level ($t$ = 4.82, $p$ < .001). This result indicated that for clinical workplace safety knowledge, decreasing anxiety and increasing mastery level of clinical workplace safety were not affected by whether users had HAI experience. In addition, users in the $G_Y$ (Friendly) group would be able to learn better through HAI-based training programs, which not only effectively decreased the anxiety of clinical workplace safety, but also increased their mastering level of clinical safety knowledge. Based on the HAI experience and user-friendly groupings, abbreviated results were shown in Tables 2-3 and replied to RQ1 (exploring the impact of HAI-based training programs on the learning performance, mastery level, and user anxiety of different HAI experience groups in clinical workplace safety knowledge). The HAI-based training programs could effectively improve the learning performance of first-time, friendly user groups on clinical workplace safety knowledge. In addition, for users who felt friendly, the HAI-based training program could also effectively decrease the anxiety of clinical work safety and increase the user's mastery of clinical work safety.

### 4.2. Exploring the impact of HAI-based training programs on different medical populations in clinical workplace safety knowledge

Based on discussions in RQ1, first-time or feel-friendly users would acquire more knowledge when learning in the proposed HAI-based clinical safety training program. Since the medical personnel in the hospital included doctors and non-doctors, this study explored the differences in the learning performance of different medical personnel between first-time and feel-friendly users. In Table 4, most of the first-time (237/319, 74.3%) or feel-friendly (231/313, 73.8%) user groups are doctors. For first-time users who belonged to the $G_N$ (Experience) group, there was a significant difference in the number of correct answers between doctors and non-doctors ($t$ = 2.38, $p < .05$). Doctors correctly answered 10.92 questions in average, which was significantly higher than 9.90 questions answered by non-doctors. There was also a significant difference in the number of correct answers between doctors and non-doctors for users who belonged to the $G_Y$ (friendly)($t$ = 2.65, $p < .01$). Doctors answered 11.10 questions correctly in average, which was also significantly higher than 9.95 questions answered by non-doctors.

For the first-time users in the $G_N$(Experience) group, there were no significant differences between doctors and non-doctors in decreasing anxiety ($t$ = -.82, $p > .05$) and increasing mastery levels ($t$ = -.18, $p > .05$). Besides, for the feel-friendly users in the $G_Y$(Friendly) group, there were also no significant differences between doctors and non-doctors in decreasing anxiety ($t$ = -1.79, $p > .05$) and increasing mastery levels ($t$ = -.55, $p > .05$). Results above implied that both doctors and non-doctors in the first-time group and in the feel-friendly group in the HAI-based clinical safety training program felt they've been receiving equal assistance with decreasing anxiety and increasing mastery level.

*Table 4.* The independent sample *t*-test results of the user perception and HAI system-based assessment

| Group | Identity | # | User perception | | | | HAI system-based assessment: Correct answers | |
|---|---|---|---|---|---|---|---|---|
| | | | Decreasing anxiety | | Increasing mastery level | | | |
| | | | Mean/Std. | *t* value | Mean/Std. | *t* value | Mean/Std. | *t* value |
| $G_N$(Experience) | Doctor | 237 | 2.63/.62 | -.82 | 2.74/.56 | -.18 | 10.92/3.89 | 2.38* |
| | Non-doctor | 82 | 2.70/.66 | | 2.76/.64 | | 9.90/3.14 | |
| $G_Y$(Friendly) | Doctor | 231 | 2.69/.56 | -1.79 | 2.81/.46 | -.55 | 11.10/3.97 | 2.65** |
| | Non-doctor | 82 | 2.80/.46 | | 2.84/.46 | | 9.95/3.13 | |

*Note*. # indicates the number of users in the group. $^{*}p < .05$; $^{**}p < .01$.

According to the user perception questionnaire results, both the first-time and the feel-friendly users, both doctors and non-doctors, felt equally helpful in decreasing anxiety and increasing mastery. In other words, at the user perception level, both doctors and non-doctors believed that the HAI-based clinical safety training program could help them equally at the psychological level, such as decreasing anxiety and increasing mastering levels. Furthermore, the doctors spent more time answering questions, and answered more questions correctly while compared to the non-doctors. In response to RQ2 (exploring the impact of HAI -based training programs on the learning performance, mastery level, and user anxiety of different medical personnel in clinical workplace safety knowledge), the HAI-based clinical safety training program was more helpful to the doctors than the non-doctors. In addition to the help at psychological level, such as decreasing anxiety and increasing mastery levels, doctors also obtained a significantly higher learning performance than non-doctors.

To understand hospital personnel's points of view of the HAI-based clinical safety training program, we collected some opinions and suggestion from doctors and non-doctors as qualitative feedback. For example, Dr. Zhang mentioned, "This is a well-designed platform. For new doctors who are not familiar with the clinical environment, this simulation training can decrease their anxiety. It is a learning platform suitable for new doctors." Ms. Zhou, the chief nurse of Emergency Department had commented as "My work partners tell me that they are more likely to experience needle stick and sharps injuries or poor medical waste management during first aid. But with a simulation training system, this unnecessary risk of workplace hazards can be reduced, which give us more confidence in clinical practice." The responses of the above-mentioned hospital members were consistent with the questionnaire response results. Both doctors and non-doctors feel that the HAI-based clinical safety training program can help them decrease anxiety and increasing mastery level.

Yang et al. (2021) had mentioned that though AI had evolved rapidly and could somehow imitate human behaviors, the fundamental difference between artificial intelligence and human intelligence was emotion, feeling and cognition. To compensate the shortage that AI may make, this study, by embedding questionnaires into the system, showed the users experienced emotional well-being after using this learning system. Therefore, our study suggests that creating a user-friendly system is also effective for medical education.

By using real-time feedback with embedded questionnaire, our system is a user-friendly, humanity based, explainable and trustworthy education platform, i.e., a humanity-centered design. Shneiderman (2020) encourages researchers to strike a delicate balance between human control and computer automation, bring it a higher level of humanity and creativity to enhance HAI utilization. In this study, we evaluated learning performance, mastery level, and user anxiety, making it a human-centered design by further assessing psychological level. We also considered it is a good example of HAI because it recognizes human feeling and maintains adaptable automation, creating a trustworthy and explainable system.

## 5. Conclusions and limitations

After three years' consecutive study from April 2018 to December 2021, we found that the HAI-based clinical safety training system for the CWM and NSSI prevention could be applied to hospital-wide medical personnel. This study explored the user's learning performance and effectiveness including decrease anxiety and increase master level of clinical work safety knowledge after HAI-based training. From the first-time and feel-friendly user's experience, this training could achieve significantly higher learning performance, decreased anxiety, and increased mastery level of clinical safety knowledge. In comparison with non-doctor users, doctors gained more benefits, such as improved learning performance and effectiveness including decreased anxiety and increased clinical safety knowledge.

As for its limitation, the subjective values were collected via questionnaire which could be biased. Possible bias may also include missing or inadequate data for intended purpose, such as belief and behavior when being asked about hypothetical or personalized question. For instance, "Are you anxious about managing clinical wastes appropriately and needle stick/sharp injuries prevention?" "Are you familiar with clinical wastes disposal and needle stick/sharp injuries prevention after HAI-based learning?" or "Are you confident in clinical wastes disposal and needle stick/sharp injuries prevention?"

Finally, according to Accreditation Council for Graduate Medical Education (ACGME), there are 6 general competencies for residents as a milestone, namely of Patient Care, Medical Knowledge, Practice-based learning and improvement, Interpersonal communication skills, Professionalism, Systems-based practice (The Accreditation Council for Graduate Medical Education [ACGME], 1999). We expect to help medical students achieve these six competencies by HAI-based learning system in the future.

As for future prospective, after massive database collection, we hope to create a platform that could not only easily extend to clinical work safety, but also integrate with medical education or other issues. We are looking forward to building a platform to develop a user-friendly and customized learning program to all fields for different levels of doctors as well as different occupations.

In conclusion, the significant increasing of the learning performance, increasing mastery level and decreasing anxiety about knowledge and skills of the CWM and NSSI prevention indicates the high acceptability among users of Human-centered Artificial Intelligence courses. Therefore, it's necessary for educational committee to keep on selecting and establishing clinical safety related topics base on the initial positive findings and our HAI training system.

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