# A Serious Game for Training Health Care Providers in Interprofessional Care of Critically-Ill and Chronic Care Patients

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*Abstract*—**Interprofessional education (IPE) is a pedagogical approach that allows health care practitioners to provide comprehensive health care through the development of a clear understanding and appreciation of the roles, expertise, and unique contributions of multiple disciplines. Despite widespread agreement on its many benefits, there are several professional, curricular, structural, and organizational factors that present significant challenges to its implementation. Interactive virtual environments or serious games offer solutions to many of these barriers while augmenting the learning of skills, knowledge and attitudes requisite in interprofessional care in an environment that is interactive, fun and engaging.**

*Index Terms*— **interprofessional education, serious games, game-based learning, collaborative learning.**

## I. Introduction

An aging population along with lifestyle and behavioral changes has contributed to a significant rise in both complex and chronic illnesses. The health system's ability to respond to these problems depends on the utilization and integration of the multiple skills and services of many different professionals, rather than those of the lone doctor, nurse or social worker. In fact, most patients interact with more than one health professional and the number of professionals involved with a patient and the importance of their ability to work together increases as the patient's needs become more complex [1]. Specifically, the care of individuals with chronic and complex problems is most appropriately accomplished through *interprofessional* models of health care delivery.

There is widespread agreement that the future of health care and the quality of patient care is dependent upon the ability of health care professionals to engage in interprofessional collaboration and care whereby comprehensive health services are provided to patients by multiple health caregivers who work collaboratively to deliver quality care within and across settings. Research has indicated that interprofessional care improves access to health care and outcomes for people with chronic and complex diseases, results in better use of clinical resources, enhances inter-professional relationships, and leads to lower rates of staff turnover [2,3]. Evidence further suggests that when dealing with rapidly deteriorating patients in a hospital setting, interventions delivered by well trained rapid response teams (RRTs) lead to a reduction in patient mortality, while a lack of knowledge and respect for the capabilities of other professionals can lead to ineffective and unsafe patient care [4].

The knowledge, skills, attitudes and behaviors required to achieve these benefits and outcomes are complex and varied and include interpersonal communications, conflict resolution, critical thinking, understanding of a patient/family-centered model of care, collaborative decision-making, an understanding of professional roles and responsibilities, and ethical practice [5,6,7,8,9]. For pre-licensure students, or students who have not graduated with their professional degree and are not licensed to practice with patients, interprofessional education (IPE) can assist in the development of skills necessary to interact and interpret the language of other disciplines treating the patient and therefore contributes to positive patient outcomes. Trainees develop an understanding of the other professions' scopes of practice, roles and expertise within the context of patient care thereby enabling them to meet multi-factorial and complex patient needs as well as minimizing biases or territoriality that often exists between health care professions.

Despite the benefits of interprofessional education, it is currently not a major component of health care education and training. What little interprofessional learning that does exist is typically not a part of "mainstream" clinical learning and is thus rarely included in the assessment process [10]. In fact, many argue that our current health professional educational system not only fails to foster interprofessional skills, but rather, the


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"discipline-specific" approach promotes territoriality and attitudes that hinder interprofessional collaboration [11, 12]. Where IPE does exist, curriculum and learning activities have focused almost exclusively on those professions achieved through university degree programs and post-degree education requiring a minimum of four years of education despite the fact that 70% of health care professionals are trained in a college environment where programs are less than four years [13].

The lack of perceived value of IPE by some maybe one barrier to its implementation but there are also many professional, curricular, structural, and organizational factors that present significant challenges to its implementation [14]. For example, effective, realistic IPE requires the participation of multiple professional programs and yet, educational institutions vary widely with respect to the combination and number of professional programs that they offer. Coordination of schedules and space are significant barriers, particularly when students from multiple programs must come together to practice. Finally, IPE is often a resource-intensive training since optimally, experiential learning rather than didactic approaches appear to be most effective [2,15,16].

### *Purpose of this Work*

Here we describe an ongoing project whose purpose is to develop a serious game (i.e., a game whose primary purpose is learning/training) to augment the learning of skills, knowledge, attitudes and behaviors requisite in interprofessional care while overcoming many of the barriers to IPE. Specifically, the serious game described here eliminates challenges related to the availability of multiple professions, coordination, and scheduling and space requirements, while minimizing the need for instructors or facilitators. At the same time, it aims to address the multiple and complex range of competencies that comprise interprofessional care for trainees in two situations: i) a critical care (rapid response) team to optimize care delivery in the management of critically ill patients, and ii) a team of health and social service professionals providing care to persons with life limiting chronic conditions who may reside in a home, hospital or long term care facility.

The serious game provides systematic practice opportunities for health professionals and trainees to develop and maintain team-related interprofessional skills. It provides a safe environment to practice these skills in a remote (online) setting and offers immediate feedback about trainees' actions that, within traditional learning models, may take weeks, months, or even years to develop.

This paper builds upon the preliminary work of Kapralos *et al*. [17] where a brief outline of the serious game was presented. Here we elaborate further providing a more extensive overview of interprofessional education, a discussion of some of the issues inherent with the current interprofessional education methods and techniques, an overview of serious games in addition to a discussion of some relevant previous work. Furthermore, we provide a detailed description of a chronic care scenario and detail its implementation (several screenshots are also provided). Finally, we detail plans for future work.

## II. BACKGROUND

Trainees in the health professions are increasingly being exposed to a variety of unsupervised learning context including virtual learning environments, such as serious games. While some opportunities for unsupervised learning have always been available (e.g., learning how to take a patient history from a textbook), several recent factors have conspired to increase both the number of these opportunities and the sophistication of the skills and knowledge that can be learned in the unsupervised context. For example, the advent of increasingly elaborate educational technologies such as simulation, virtual patients, and various asynchronous learning tools has allowed trainees the convenience of learning on their own schedules rather than being restricted by the availability of clinical teachers. This affordance has been seen as a great advantage not only for the trainees themselves but also from a resource perspective, as it has helped to reduce the demands on clinical educators [18]. Furthermore, from an ethical perspective, these technologies have removed the need to place patients at risk when trainees are learning clinical skills, thereby decreasing the pressure on supervisors to provide direct clinical oversightof the learning experience. The loss of this ethical rationale for supervised learning in the traditional clinical context has allowed resource issues to become the prominent driving factor in the decision to allow trainees to learn without expert guidance.

Two additional pressures arise from the theoretical domain. First, from the perspective of "learning how to learn," an increased use of unsupervised learning may be justified on the premise that allowing trainees to "figure it out themselves" will give them practice with the lifelong learning skills they will need to maintain competence in later practice. Second, there is ample evidence in the education literature suggesting that a trainee who is involved actively in her education will benefit more than when an educator excessively controls the process [19,20]. Thus, interestingly, as patient safety issues have placed a heavy pressure on the need to decrease trainee autonomy in the clinical context [21], the confluence of the various factors described above has resulted in more unsupervised, self-guided learning opportunities for trainees than ever before. While these various pressures provide a sensible logic for a shift toward unsupervised learning in the nonclinical context, we must be cautious to ensure that this shift is not simply an unreflective drift away from supervised, educator-guided learning. As Cook [22] has suggested, educational research activities have long lagged behind advances in technology. As a result, technologies, rather than innovations in instruction and learning theory, often drive educational change [23,24] and this may be truer for the unsupervised, self-guided learning context than any other area in health professions education. Further, learning theorists [25,26] would argue that excessive unsupervised learning is problematic and, there are many reasons for educators to supervise trainee learning. For example, it has been demonstrated that educators can diagnose the trainee's learning needs and focus their learning efforts more effectively [27]. In addition, without informed corrective feedback, trainees may form bad habits and incorrect judgments about their learning. Thus, while there may be good reasons to increase our reliance on unsupervised, self-guided learning for our trainees in the nonclinical context, if we are not reflective and strategic in this shift we run the risk, in the words of Lee Brooks [28] "of turning our curricula into the equivalent of arranging a swimming lesson by sinking a boat: Those who survive learn how to keep their heads above water, not how to swim effectively". Another factor influencing the use of unsupervised learning environments is the educational content. Although evidence is mounting that self-regulated learning maybe a feasible option for acquisition of individual skills [29], there is no evidence that such learning is effective in an interprofessional context where the expectation is that trainees collaborative with multiple professions in the delivery of comprehensive patient care.

The new conceptualization of self-guided learning therefore requires educators to recognize that it is context- and content-specific [30,31]. This specificity means that the particular set of competencies that the trainees are learning may impact and determine the best training approach. Consequently, training regimes will have to be constructed independently and iteratively with the specific context in mind, be it simulation, web-based modules, or clinical training experiences. Recently, attention has been paid to the models of supervision that can help trainees practice autonomously and effectively [32]. Serious games are one such model; through the use of game-based methods and techniques (e.g., adaptive game-play whereby the game's level of difficulty is adjusted depending on the user's actions) can provide a supervised form of training/learning can be achieved while trainees practice autonomously (in the absence of the educator) regardless of their physical location.

### B. *Serious Games*

Although no particularly clear definition of the term is currently available, serious games usually refer to games that are used for training, advertising, simulation, or education and are designed to run on personal computers or video game consoles [33]. They have also been referred to as "games that do not have entertainment, enjoyment, or fun as their primary purpose" [34] but more formally be defined as an interactive computer application, with or without a significant hardware component, that i) has a challenging goal, ii) is fun to play and/or engaging, iii) incorporates some concept of scoring, and iv) imparts to the user a skill, knowledge, or attitude that can be applied to the real world [35].

Serious games "leverage the power of computer games to captivate and engage players for a specific purpose such as to develop new knowledge or skills" [36]. In addition to promoting learning via interaction, there are other benefits. They allow users to experience situations that are difficult (even impossible) to achieve in reality due to factors such as cost, time, and safety concerns [37]. Serious games support the development of various skills including analytical and spatial, strategic, recollection, psychomotor skills and visual selective attention [38]. Improved self-monitoring, problem recognition and solving, improved short-and long-term memory, and increased social skills have also been attributed to serious games [38].

Although the term serious games is rather new, dating back to 1992 [39], serious games and virtual simulations in general have been used by the United States military, medical schools, and in academia before the term was introduced [35]. Game-based technologies have also been used for many years as training simulators for vehicle control, such as flight simulators. Through game constructs, realistic situations can be simulated to provide valuable experience to support discovery and exploration in a fun and engaging manner while saving money and lives. Advances in video game technologies have enabled and enriched serious games research, from interaction with and modification of data-driven, complex 3D models performed in real time on graphics processing units, to robust artificial intelligence and simulation components. Conversely, through creatively leveraging commodity video game technologies in new ways, serious games research and development has helped the video game by expanding the horizons of games to include scientific simulation and visualization, industrial and military training, medical training and education, geographic information systems.

It has been estimated that currently, the serious games industry generates 2.1 billion in revenue globally and with an expected average annual growth rate of 47% in the next five years; by 2015 sales will reach 15.0 billion [40]. It is also anticipated that the healthcare and health-related serious games will drive this growth, particularly if the industry is able to overcome its challenges and limitations. Specifically, there is a lack of research that investigates the technological conditions under which virtual learning can be maximized, as well as a lack of research that links virtual learning with proven educational theory and practice.

Tashiro *et al*. [41,42,43,44] developed a typology of serious games for healthcare education and explored the strengths and limitations of serious games for improving clinical judgment. They found that generally, serious games do not meet the standards for instructional materials set forth by the *US National Research Council*, and the *Federation of American Scientists* and identified seven areas that require research and improvements for the effective development of serious games:

- Disposition to engage in learning.
- Impact of realism on learning.
- Threshold for learning.
- Process of cognitive development during knowledge gain.
- Stability of knowledge gain (retention).

- Capacity for knowledge transfer to related problems.
- Disposition toward sensible action within clinical settings.

### C. Relevant Previous Work

The Center for the Advancement of Distance Education (CADE) within the School of Public Health at the University of Illinois (Chicago) has developed a public health simulation within Linden Lab's Second Life that allows public health workers to test their skills in scenarios ranging from bioterrorism attacks, smallpox outbreaks, to natural disasters [45]. Their simulation primarily focuses on first response preparedness and although it doesn't explicitly focus on Interprofessional education, it does permit multiple users to interact and work collaboratively.

Heinrichs *et al*. [46] developed three virtual worlds for team training and assessment in acute-care medicine for training of: i) emergency department (ED) teams to manage individual trauma cases, ii) pre-hospital and in-hospital disaster preparedness, and iii) ED and hospital staff to manage mass casualties after chemical, radiological, nuclear, or explosive disasters. Evaluations of these virtual worlds indicated that virtual emergency department simulations are able to provide "repeated practice opportunities in dispersed locations with uncommon, life-threatening trauma cases in a safe, reproducible, flexible setting" [46].

TriageTrainer is a prototype 3D-based serious games developed by TruSim (a division of *BlitzGameStudios*), designed to develop accurate decision making in the Triage. The game places players/trainees in the scene of an explosion in a busy street and the player's job is to prioritize the multiple casualties for treatment. They must follow set protocols to make their decision. Characters in the game are of high fidelity and react emotionally and physically (via auditory and visual cues) to their injuries. In controlled trials conducted in the United Kingdom, the TriageTrainer was found to be statistically significantly better at developing accuracy in prioritizing casualties and in supporting students to follow the correct protocol to make their decision when compared to when compared to a "traditional learning method" (TriageTrainer, Website-TrueSim - http://www.trusim.com/).

Pulse!! is an immersive virtual learning environment for training health care professionals (civilian and military) in clinical skills with the aim of improving responses to injuries sustained during catastrophic incidents, such as combat or bioterrorism [47]. It is being developed in a partnership by Texas A & M University - Corpus Christi and BreakAway Games Ltd., and is funded by the Department of the US Navy's Office of Naval Research. Pulse!! features a "cutting-edge" 3D hospital environment with high fidelity patients and is highly interactive with accurate physiological models and fluid dynamics to provide realistic blood flow through the human body.

Although the work described above permits multiple users to collaborate, unlike the serious game presented here, they do not focus specifically on the development of interprofessional skills. More importantly, the work undertaken for the interprofessional serious game aims to address the challenges and gaps identified by Tashiro *et al*. [41,42,43,44]. Specifically, we will examine: i) the effects of audio-visual fidelity on knowledge transfer (e.g., is high fidelity associated with improved knowledge acquisition and retention?), ii) the effects of audio-visual fidelity on immersion and their ability to perform specific tasks, and iii) the effects of the interaction of multi-cues (graphical and auditory cues in particular) on knowledge acquisition and retention. In addition, through randomized control studies, we will compare the effects of facilitated, directed, and self-regulated learning in a serious game on knowledge acquisition and retention. Finally, our research will examine the effects of three different educational modalities (didactic, physical simulation and serious game) on knowledge and skill acquisition and trainees ability to transfer these skills to a clinical environment.

## III. Interprofessional Education Serious Game

### A. Modular Synthetic Training Research Evaluation and Extrapolation Tool (mSTREET)

The IPE serious game described in this paper has been developed using the *Modular Synthetic Training Research Evaluation and Extrapolation Tool (mSTREET)*. mSTREET is a serious game 3D software platform, or framework, for delivering computerized virtual training and research environments in a variety of investigative and direct response settings. mSTREET provides a "base framework" for developing specific application modules which are designed to emulate the functional and behavioral processes in various disciplines. Students and educators in the supported fields can use the software to easily construct "scenarios" that can be played out in real-time, in the safe and controlled environment of a virtual 3D world.

Scenarios are structured around rigid protocol scripts that require adherence to time- or sequence-sensitive action protocols, or they can be unstructured, requiring satisfactory real-time response to emerging events and information. Trainee responses can take the form of immediate, direct action in real-time (e.g., taking the blood pressure of a patient in a critical care ward), or the issuance of recommendations for further action by a third party (e.g., a community health care provider recommending that soft drinks be removed from elementary schools in order to combat childhood obesity). When recommendations are made, the player has the option of "fast-forwarding" in time see any effects resulting from their recommendations. Instructors can test students using the same scenarios with fixed scoring criteria, and use the resulting scores to generate a grade.

mSTREET also incorporates a mechanism to allow "games within the game" whereby at various points, the user can be presented with a "sub-game" requiring the user to perform a task related to the step they are performing. In the simplest case, sub-games can consist of one or two multiple choice questions randomly selected from a pre-defined list of questions. Answering these multiple questions correctly allows the user to accumulate points or to proceed to a next level whereas incorrect responses lead to a deduction of points.

Non-playing characters (NPCs) are directed by *artificial intelligence* (AI) routines or are table-driven (similar to an expert system) according to rule sets designed for the specific field. NPCs can also be operated remotely by other professionals in the emulated field.

Finally, mSTREET presents a problem-based learning (PBL) approach whereby the student/trainee is presented with a complex scenario that does not have a simple answer. Students engage with the problem, perform research, gather information, perform analysis and evaluate hypotheses through experimentation.

### *B. Interprofessional Care of the Chronically Ill (CCIPE) mSTREET Module*

The IPE mSTREET module supports an "online multi-player" environment allowing trainees to participate from remote locations. Scenarios may involve a critically ill or chronic care patient.

In the case of the critically ill patient, the patient requires the immediate attention of a critical care rapid response team which consists of a number of healthcare professionals including doctors, respiratory therapists, and nurse.Each of the response team members has a corresponding avatar within the simulation which is controlled by one trainee/student in a "first-person-shooter" manner (see Fig. 1. for a sample screenshot). The patient presents with several clinical concerns which will increase in complexity and severity if not responded to appropriately.

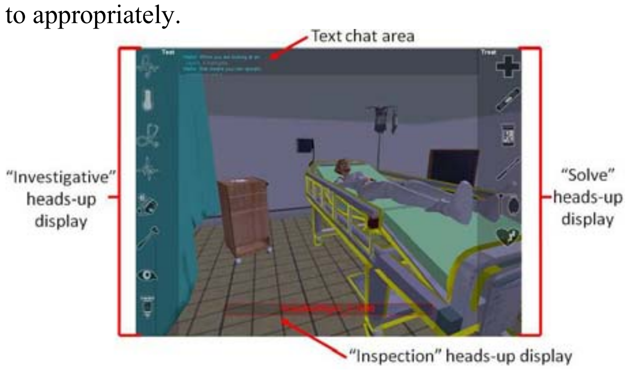


Figure 1. Sample screenshot of a critical care scenario with corresponding GUI layout. The "Text chat area" allows the multiple players to communicate with each other, the "heads-up" displays provide the player with a list of available options (e.g., to access various devices, and medication).

The goal of the trainees is to stabilize the patient and this can only be accomplished through the collaborative of response of the team members who are able to communicate and interact with each other, the patient, and equipment within the virtual environment to accomplish their task.

In the case of the serious game for training interprofessional care of the chronically ill patient, players from multiple professions must critically assess the patient's physical, social and emotional needs to devise and implement a plan of care that meets the patient's complex and multi-factorial needs. A detailed scenario of this game is provided in the following section.

The mSTREET IPE module provides scenario-based training to enable personnel to interact with other professionals, patients, and family members of the patient, in chronic and critical care situations. The training will be carried out in a 3D virtual environment that simulates the real world environment from a first-person viewpoint, and provides visual, audio, and situational cues that reflect the real-world foreign environment. The IPE module also provides trainers and scenario creators with the tools needed to generate interactive dialogs with simulated people using artificial intelligence techniques (known as Non-Player Characters or NPCs). Dialogs will be either self-contained, or chained together between different NPCs, with or without outcome dependencies.

Learners are provided with dialog- and action-based feedback in real-time or replay modes. When operating in teaching mode, learners are also be able to track the status of an interaction or dialog as they negotiate the interaction with the member or members of the foreign culture.

Through the mSTREET platform, the IPE module supports a multi-modal education tool that provides instructors with the ability to change operation modes based upon their educational requirements. *Teaching mode* supports "start-stop" capabilities, on-screen tips, hints, and directions. *Training mode* supports the ability to iterate through a given scenario many times, with scoring providing performance feedback. Testing mode will provide scoring under specified constraints, such as time or topic avoidance. *Research mode* is not formally managed by the platform, but instead reflects the ability of researchers to change a large variety of module and platform variables and settings, as well as logging processes, state changes, and dynamic values.

### *C. Example Scenario – Diabetic Homecare Client with Mobility Restrictions*

A nurse player (trainee/user) is inserted into a scenario when she emerges from her vehicle in front of the home of a homecare client with diabetes and severe mobility restrictions. The player maneuvers the avatar using the mouse and keyboard to observe the scene. The scenario includes various "observables" that embody significant information about the environment in which the subject man lives. In this case, the scenario includes access to the home that requires climbing six steps from the sidewalk to the front porch of the house. There is no access ramp visible for use by a wheelchair or a walker. This information is encoded along with the 3D model used in the scene that represents the front steps. The player may take note of the front stairs as an important client care issue and can do this in one of three ways, depending on the operating mode of the platform, as determined by the instructors or the scenario developers:

1. **Testing**: The player types his/her note, freeform, into an on-screen notepad that is summoned by a key press (see Figure 2). Human evaluators (i.e., the instructor) can examine the note for usefulness and accuracy after the scenario is finished.

2. **Training**: The player focuses a cursor over the steps in question, and chooses the "Take Note" command, causing any information that the software knows about the steps to be automatically recorded into the notepad. The player is scored positively for obtaining useful and relevant notes, and scored negatively for obtaining irrelevant or useless notes.

3. **Teaching**: The player focuses a cursor over the steps, a note is automatically taken by the software, and an alert is shown and sounded audibly indicating to the player that a significant piece of information has been found. In this mode, the significance of the observation can be explained to the player before the player is allowed to move on.

As the player proceeds into the house, she documents her various observations and using an interaction system, interviews the subject with a directed menu system of query/response options that have been created by the scenario designers. An on-screen command system will be scripted to provide the player with a collection of potential actions including those which tap into the competencies of interprofessional care such as critical thinking, an understanding of professional roles, and interprofessional communications. For example, the nurse, having assessed the patient's mobility and his home environment may initiate a referral to a physiotherapist to assist the client with his mobility restrictions so that he may safely navigate his front stairs and participate in a prescribed fitness regime. She will be required to present her assessment and collaborate on a plan of action with a member of another profession and the client himself. The scenario will incorporate opportunities to practice and be evaluated with respect to interpersonal communications, conflict resolution, critical thinking, patient/family-centered care, collaborative decision-making, understanding of professional roles and responsibilities, and ethical practice. Sample screenshots are provided in Figures 3 and 4 and illustrate the environment that the users may encounter as they guide their avatar to the patients home.

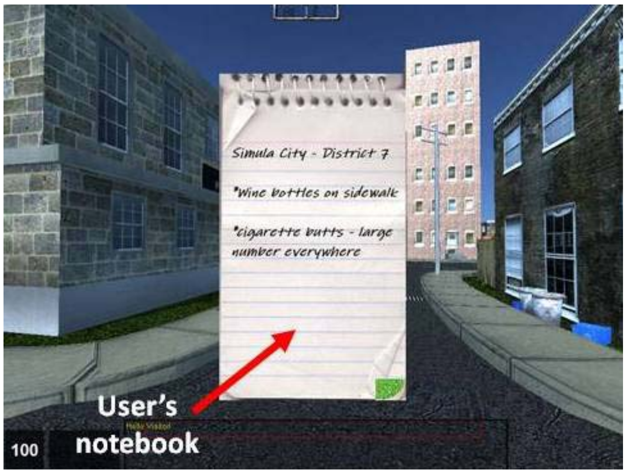


**Figure 2**. "Notebook" option allows users to take notes. In this example, the user has made a comment regarding, the environment/area that may be outside the patient's home and may indirectly affect them.


Figure 3. Sample screenshot within the community.


Figure 4. Sample screenshot within the community.

## IV. Conclusions

Interprofessional care occurs when comprehensive health services are provided to patients by multiple health caregivers who work collaboratively to deliver quality care within and across settings. This model of care is particularly relevant in chronic and critical care because of its potential to addresses multi-factorial, complex problems requiring the utilization and integration of the multiple skills and services of many different professionals.

Despite the benefits of interprofessional education, it is not yet well integrated into the curriculum of health care professional programs. The curriculum that does exist has targeted the relatively small portion of health care programs offered in the university sector and has largely ignored those professionals trained in college-based programs.

There has been a significant effort in the development of simulation applications related to health and healthcare and it is anticipated that healthcare (including surgical training) will experience the greatest growth in serious games in part, as a consequence of the increased resource consumption required for clinical, “hands-on training”. Specifically, simulated training with virtual learning environments and serious games offer solutions to a number of challenges associated with clinical education by reducing pressure for clinical training environments, addressing the ethical imperative to reduce patient exposure to trainees, improve patient and professional safety, and reduce resource needs (e.g., monetary, faculty time, and time in specialized facilities, such as operating rooms and critical care units. Serious games and virtual simulations offer safe and economically viable alternative to traditional training methods and techniques.

Here we have described a serious game for interprofessional education and training that supports a remote, multi-user environment. The game provides a fun, interactive, and engaging learning environment and eliminates the risks and ethical issues associated with students learning on real patients. It also addresses pressures (e.g., cost, time and appropriate supervision) associated with training in a clinical environment.

Future work will include evaluating the educational effectiveness of the serious game with health care practitioners and students at both the college and university levels. This may also include a case-controlled study whereby students exposed to the serious game are compared to a control group receiving training through a traditional, didactic approach. Future work will also examine questions such as: How much fidelity (i.e., realism) is needed to maximize knowledge transfer? How can learning outcomes be “scaffolded” to advance and excel student learning? What is the impact of self-regulated learning in a virtual learning environment on learner outcomes? Is training of professional skills through gaming more effective and cost-efficient than traditional simulation and didactic learning? The answers to such question will lead to more effective serious games.

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## REFERENCES

[1] L. A. Headrick, P. M. Wilcok, and P. B. Batalden, “Interprofessional working and continuing medical education,” *British Medical Journal,* vol. 316, pp. 771, 1998.

[2] D. Freeth, M. Hammick, S. Reeves, I. Koppel, and H. Barr. *Effective Interprofessional Education: Development, Delivery & Evaluation*. Oxford, UK: Blackwell, 2005.

[3] S. Reeves, M. Zwarenstein, J. Goldman, H. Barr, D. Freeth, M. Hammick, I. Koppel. *Interprofessional education: effects on professional practice and health care outcomes*. Cochrane Database of Systematic Reviews 2008, Issue 1. Art. No.: CD002213. DOI: 10.1002/14651858.CD002213.pub2.

[4] L. Kohn, J. Corrigan, and M. Donaldson. *To Err is Human: Building a Safer Health System*. Washington, DC .USA: National Academy Press, 2000.

[5] D. D’Amour, and I. Oandasan. “Interprofessionality as the field of interprofessional practice and interprofessional education: An emerging concept,” *Journal of Interprofessional Care*, Supplement 1, pp. 8-20, 2005.

[6] T. J. K. Drinka, “Applying learning from self-directed work teams in business to curriculum development for interdisciplinary geriatric teams,” *Educational Gerontology*, vol. 22, pp. 433–450, 1996.

[7] M. Fitzpatrick, “Interdepartmental collaboration: Focus on outcomes,”. *Seminars in Perioperative Nursing*, vol. 5, no. 1, pp. 47–50, 1996.

[8] P. Hall, “Interprofessional teamwork: Professional cultures as barriers,” *Journal of Interprofessional Care*, vol. 19, no. 2, pp. 188–196, 2005.

[9] V. Wood, A. Flavell, D. Vanstolk, L. Bainbridge, and L. Nasmith, “The road to collaboration: Developing an interprofessional competency framework,” *Journal of Interprofessional Care*, vol. 23, no. 6, pp. 621-629, 2009.

[10] K. McPherson, L. Headrick, and F. Moss. “Working and learning together: Good quality care depends on it, but how can we achieve it?” *Quality in Health Care*, vol. 10 Supp. II, pp. ii46-ii53, 2001.

[11] D. Baldwin. “The case for interdisciplinary education”, in *Mission Management: A New Synthesis*, E. Rubin, Eds. Association of Academic Health Centres, Washington, DC. USA, 1998.

[12] D. L. Parker and D. S. Wrtheimer. Incorporating internal medicine residents into an interdisciplinary geriatric assessment team. Academic Medicine, vol. 72, no. 5, pp. 451, 1997.

[13] D. Cook, “Models of interprofessional learning in Canada,” Journal of Interprofessional Care. Vol. 19, no. 2, pp. 107 -115, 2005.

[14] S. M. Buring, A. Bhushan, A. Broeseker, S. Conway, W. Duncan-Hewitt, L. Hansen,. And S. Westberg “Interprofessional education: definitions, student competencies, and guidelines for implementation,” *American Journal of Pharmaceutical Education*, vol. 73, no. 4, Article 59.

[15] D. Rosenfield, I. Oandasan, S. Reeves, “A participatory approach to interprofessional education research: Students researching with their peers,” *Journal of Interprofessional Care*, vol. 23, no. 6, pp. 676–678, 2009.

[16] C. O’Halloran, S. Hean, D. Humphris, and J. Macleod-Clark, “Developing common learning: the New Generation

Project undergraduate curriculum model," *Journal of Interprofessional Care*, vol. 20, no1, pp. 12-28, 2006.
[17] B. Kapralos, M. Hogan, C. Mallette, A. Wood, K. Finney, A. Hogue, and A. Dubrowski. Serious games for Interprofessional education for critical care response teams. *Group Awareness in Online Work, Learning, and Games Workshop* at *HCI 2010*. Abertay, Dundee, Scotland, September 7, 2010.
[18] ACGME. Accreditation Council for Graduate Medical Education. Outcome Project: Competencies. 2010. Available at: http://www.acgme.org/outcome/comp/compHome.asp.
[19] B. J. Zimmerman, "A social cognitive view of self-regulated academic learning," Journal of Educational Psychology, vol. 81, pp. 329 –339, 1989.
[20] M. S. Knowles, *Self-Directed Learning: A Guide for Learners and Teachers*. New York, NY. USA : New York Association Press, 1975.
[21] T. J. Kennedy, L. Lingard, G. R. Baker, L. Kitchen, and G. Regehr, "Clinical oversight: Conceptualizing the relationship between supervision and safety," *Journal of General Internal Medicine*, vol. 22, pp.1080 –1085, 2007.
[22] D. A. Cook. "The failure of e-learning research to inform educational practice, and what we can do about it", *Med Teach*, vol. 31, pp. 158 – 162, 2009.
[23] R. Kneebone, "Evaluating clinical simulations for learning procedural skills: A theory-based approach," Academic Medicine, vol. 80, pp. 549 –553, 2005.
[24] P. H. Winne, and D. B. Stockley, "Computing technologies as sites for developing self-regulated learning," in *Self-Regulated Learning: From Teaching to Self-Reflective Practice,* D. H. Schunk, B. J. Zimmerman, Eds. New York, NY: The Guilford Press, 1998, pp. 106 –137.
[25] L. S. Vygotsky, *Mind in Society: The Development of Higher Psychological Processes*. Oxford, England: Harvard University Press, 1978.
[26] J. S. Bruner. *The Culture of Education.* Cambridge, MA. USA: Harvard University Press. 1996.
[27] K. A. Ericsson. "An expert-performance perspective of research on medical expertise: The study of clinical performance", *Medical Education,* vol. 41, pp. 1124 – 1130, 2007.
[28] L. Brooks. Personal communication, 1997.
[29] R. Brydges, H. Carnahan, O. Safir, and A. Dubrowski. "How effective is self-guided learning of clinical technical skills? It's all about process". Medical Education, vol. 43, pp. 507–515, 2009.
[30] K. W. Eva, and G. Regehr. "Self-assessment in the health professions: A reformulation and research agenda", *Academic Medicine*, vol. 80, pp. S46 –S54, 2005.
[31] L. K. Son, and J. Metcalfe, "Metacognitive and control strategies in study-time allocation,". Journal of Experimental Psychology Learning Memory and Cognition, vol. 26, pp. 204 –221, 2000.
[32] T. J. Kenned, L. Lingard, G. R. Baker, L. Kitchen, and G. Regehr, "Clinical oversight: Conceptualizing the relationship between supervision and safety," *Journal of General Internal Medicine*, vol. 22, pp. 1080 –1085, 2007.
[33] T. Susi, M. Johannesson,, and P. Backlund. *Serious games - an overview.* Technical Report No. HS-IKI-TR-07-001. School of Humanities and Informatics, University of Skovde, Sweden, 2007.
[34] D. Michael, and S. Chen, *Serious games: Games that educate, train and inform*. Boston, MA. USA: Thomson Course Technology, 2006.
[35] B. Bergeron. *Developing serious games*. Hingham, MA. USA: Thomson Delmar Learning, 2006.
[36] K. Corti, *Game-based learning; a serious business application*, PIXELearning. Coventry, UK.., 2006.
[37] K. Squire and H. Jenkins, "Harnessing the power of games in education," *Insight*, vol. 3. No. 1, pp. 5-33, 2003.
[38] A. Mitchell, and Savill-Smith., *The use of computer and video games for learning: A review of the literature*. www.LSDA.org.uk. London, UK.., 2004.
[39] B. Sawyer. In U. Ritterfeld, M. Cody, and P. Vorderer Eds.. Serious Games Mechanisms and Effects, New York, NY, USA: Routledge 2009.
[40] IDATE Market Analysis and Consulting Group. "Serious Games: A 10 billion Euro market in 2015", 2010.
[41] J. Tashiro. What really works in serious games for healthcare education. In *Proceedings of the 2009 Future Play @ GDC Canada*, Vancouver, British Columbia, Canada, May 3-4, 2009.
[42] J. Tashiro, "Ethical analysis of publisher and faculty roles in building and using electronic educational products," *Journal of Electronic Commerce in Organization,* vol. 7, no.1, pp. 1-17, 2009.
[43] J. Tashiro, and D. Dunlap, "The impact of realism on learning engagement in educational games," In *Proceedings of ACM Future Play 2007.* Toronto, Ontario, Canada, November, 2007.
[44] J. Tashiro, P. Rowland, "What works: Empirical approaches to restructuring courses in biology and environmental sciences", in *Models of Innovation in College Science Teaching,* A. McNeal and C. D'Avanzo Eds. Orlando, Florida, USA., Harcourt Brace and Company, pp 163-187, 1997.
[45] L. Hoffman, and C. Kelly, "First responders meet Second Life: Public health enters the virtual world", *Medill Reports*, 2009 (Feb. 4). Retrieved March 23, 2010 from http://news.medill.northwestern.edu/chicago/news.aspx?id =114473.
[46] W. L. Heinrichs, P. Youngblood, P. M. Harter, and P. Dev, "Simulation for team training and assessment: Case studies of online training with virtual worlds," *World Journal of Surgery*, vol. 32, no. 2, pp. 161-170, 2008.
[47] C. L. Johnston, and D. Whatley, "Pulse!! – A virtual learning space project," *Studies in Health Technology and Informatics*, vol. 119, pp. 240-242, 2005.

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