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Developing the Serious Games potential in nursing education

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SUMMARY

Shortened hospital stays, high patient acuity and technological advances demand that nurses increasingly make decisions under conditions of uncertainty and risk (Ebright et al., 2003). With rising trends towards out-patient care, nurses will need to perform complex problem-solving within a dynamic and changing environment for which there is not one clear solution (Schofield et al., 2010; Wolff et al., 2009). The development of sharp clinical reasoning skills, as well as skills in detection, monitoring, investigation and evaluation are therefore essential (Aitken et al., 2002). Yet few nursing students have long-term exposure to home-care and community situations. This is primarily due to scarce human resources and the time-consuming requirements of student supervision (Duque et al., 2008). When students are given the opportunity to experience home-care or community visits these tend to be unstructured leading to wide variations in their competencies. New pedagogical tools are needed to adequately and consistently prepare nurses for the skills they will need to care for patients outside acute care settings.

Advances in Information and Communications Technologies (ICT) offer an opportunity to explore innovative pedagogical solutions that could help students develop these skills in a safe environment. A three-phased project is underway that aims to create and test a Serious Game to improve nurses' clinical reasoning and detection skills in home-care and community settings. The first phase of this project involves the development of a scenario, the game engine and the graphic design and will be the focus of this paper. The second and third phases will test the Serious Game as an educational intervention and will be reported in subsequent papers.

Introduction

Health care systems around the globe are experiencing substantial changes in their financing, structure and delivery (Economist Intelligence Unit, 2011; World Health Organization, 2012). An ageing population, rising rates of chronic illness and advances in medical technology have highlighted the growing ineffectiveness in focusing funds on tertiary care rather than on strengthening primary lines of defence (health promotion, disease prevention and chronic illness management) (World Health Organization, 2008). Increasingly, decision-makers are beginning to appreciate the economic and social value of patients spending less time in acute-care settings. Especially for those patients living with chronic conditions or requiring minor surgical interventions, there have been efforts to favour out-patient care with most of the recovery occurring in patients' homes or in out-patient clinics (Schoen et al., 2008; World Health Organization, 2008).

The opportunity for patients to remain at home to manage chronic conditions or recover from post-operative surgery has been shown to have a number of advantages (Frieden, 2010). This is particularly relevant in the elderly population for whom a hospital stay can have deleterious effects on their overall health (Hayashi et al., 2007; Tollman et al., 2008). Notwithstanding the risks involved in terms of nosocomial infections and other untoward events related to hospital-stays, there are positive reasons for patients to remain in their homes and avoid hospitalisations. These include a better quality of life, a sense of independence and functionality, and better interaction with family and friends (Duque et al., 2008; Hayashi et al., 2007). Moreover, the home is an ideal opportunity for health care professionals to observe the context in which patients live and make health care decisions. It allows the professional to identify potential risk factors (such as falling, poor diet or limited access to health care) and take measures to avert accidents that could contribute to the deterioration of health and a return to the hospital.

Despite the need for such skills, home and community care are not emphasised in most health care curricula (Duque et al., 2008; Tanner, 2010). In nursing education clinical placements focus on developing graduates equipped to function in hospital settings (Tanner, 2010). Yet the role and practice of nurses working in home-health or within community settings are quite different from those in acute care

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(Aitken et al., 2002). Whilst nurses in all settings must be competent in their clinical reasoning; those clinicians outside the acute care setting work in conditions of increased autonomy and unpredictability (Schofield et al., 2010; Wolff et al., 2009).

The top three reasons for adverse patient outcomes are a failure to properly diagnose, failure to institute appropriate treatment and inappropriate management of complications, each relating directly to poor clinical reasoning (CR) skills (Levett-Jones et al., 2010). Hence, fine-tuned CR skills are essential because nurses who lack them fail to detect impending patient deterioration, resulting in a failure to rescue (Aiken et al., 2003; Levett-Jones et al., 2010). Nurses with little experience in CR can have difficulty in differentiating between clinical problems that need immediate attention and those that are less acute and they demonstrate a tendency to make errors in time sensitive situations where there are large amounts of complex data to process (ONeill et al., 2005). These detection skills are equally relevant in community and home-care settings where patients live with and manage their chronic disease.

Since CR skills cannot be developed through simple observation, a structured educational approach with active engagement in deliberate practice is needed to teach nurses the process and steps of clinical reasoning (Ericsson et al., 2007). Indeed a method guiding clinical decision-making can ensure more consistent and safe clinical practice and mitigate the uncertainty and complexity of complex situations. Such a systematic process of thought can facilitate the development of transferable cognitive processes that are enriched by discipline-specific knowledge, evidence-based practice, experience, pattern-recognition and priority-setting (Ebright et al., 2003; Tanner, 2010; Williams et al., 2011). Since clinical reasoning is considered to be the precursor to decision and action, it is an essential element on which to focus pedagogical efforts (Simmons, 2010).

Understanding Clinical Reasoning

Definitions

Whilst Clinical reasoning (CR) is viewed as an indispensable skill for nurses and has been the topic of numerous papers and much debate within the literature (Tanner, 2006; Ferrario, 2004; Judd, 2005), there remains a lack of consensus surrounding its accurate definition. This makes it challenging to clearly outline the process underlying CR and creates confusion when trying to distinguish it from other similar terms, such as clinical judgement, critical thinking, decision-making, diagnostic reasoning and problem-solving (Thompson and Dowding, 2002).

Higgs et al. (2008, p.4) have offered one definition of CR, describing it as “a context-dependent way of thinking and decision-making in professional practice to guide actions.” Tanner (2006) presents CR as a process by which nurses make clinical judgements by selecting alternatives, weighing the evidence, using intuition and recognising patterns. The CR process allows nurses to consider multiple variables, prioritise competing health care needs, negotiate the interests of different stakeholders and inform their decisions on the best available evidence (Tanner, 2006). Levett-Jones et al. (2010) point to the necessity of linking the five rights of clinical reasoning, allowing the student to collect the right cues and take the right action for the right patient at the right time and for the right reasons.

A recent concept analysis incorporates these different definitions, as well as the literature from psychology and medicine, and offers much-needed clarification of the concept. It provides the definition adopted in this project (Simmons, 2010, p.1155): “Clinical reasoning in nursing is a complex cognitive process that uses formal and informal thinking strategies to gather and analyse patient information, evaluate the significance of this information and weigh alternative actions”. Included in CR is both the structure and process of self-regulated learning that facilitates the acquisition of critical and metacognitive thinking, awareness, knowledge and skills over time (Kautz et al., 2005). It is important to note that clinical reasoning is not a linear process but can be conceptualised as a cycle of linked cognitive processes (Levett-Jones et al., 2010).

Understanding clinical reasoning also means recognising its evolving nature. Nurses' CR will differ according to their experience and domain-specific knowledge (Benner, 1984). Novice nurses, for example, can only identify a few patient cues, have a limited ability to cluster these cues to pick up patterns and have difficulty in identifying complex diagnoses (Benner, 1984; Benner et al., 1992). Expert nurses, on the other hand, have a number of experiences to draw from when reasoning about complex issues and tend to employ informal thinking strategies (Tanner, 2006). These expert nurses often do not rely on rules and logical thought processes in their decision-making, but instead use abstract principles and can perform high-level care without conscious awareness of the knowledge they are using (Benner, 1984; Woolery 1990). This automaticity (believed to occur as memory retrieval becomes faster from repeated practice and bypasses normal processing (Palmeri, 1997)), means these experts find it difficult to verbalise their thinking and explain cognitive processes that seem tacit and implicit.

As such CR remains a complex, mostly invisible process that is often largely automatic and therefore not readily accessible to others in teaching, practice or research. In order for students and novice nurses to learn to manage complex clinical situations and develop their CR skills, a better grasp of the underlying processes are needed. A number of models have been proposed to make these seemingly automatic or instinctive cognitive processes more explicit and clear (Levett-Jones et al., 2010).

Clinical Reasoning Models

To attempt to illustrate the cognitive processes underlying CR, different theoretical and conceptual frameworks offer guidelines for clinical practice. The subjective expected utility theory (SEUT), for example, with its assigned values, expected outcomes and estimated probabilities (Von Neumann and Morgenstern, 2007), finds an application in the development of algorithms such as in Basic Life Support (BLS) and Advanced Cardiac Life Support (ACLS). The information processing theory (IPT) alternatively focuses on process by trying to explain *how* decisions are made and represents decision-making as a multi-dimensional, cyclical and recursive process of gathering information, weighing alternative options and making a final decision (Newell and Simon, 1971). Whilst these and a number of other models (i.e. hypothetico-deductive reasoning; pattern recognition; forward reasoning-backward reasoning; knowledge reasoning integration; and intuitive reasoning), have been proposed, Higgs and Jones (2000) argue that given its complex nature and the context-dependent nature of decision-making, there can be no *single* model of clinical reasoning. Indeed, while “decision-analysis” (a hypothetico-deductive approach) has been preferred in medicine to understand the concept of CR and to accurately diagnose a disease, nursing requires a different approach.

Higgs et al. (2008) propose a nursing model that includes multiple key elements such as cognition, metacognition, knowledge and context (patient and environment); whilst Kautz et al. (2005) have developed a model integrating the Outcome Present State Test (OPT) model (Pesut and Herman, 1999) with the theory of self-regulated learning (Bandura, 1997) to help students master higher order thinking skills that support effective clinical reasoning (Kuiper and Pesut, 2004). Whilst comprehensive, these models do not provide a clear and systematic clinical reasoning model that can be easily operationalised for the purposes of developing pedagogical activities to be included in an immersive and interactive Serious Game scenario.

Levett-Jones et al.'s (2010) Clinical Reasoning Cycle (CRC) model provides such a systematic approach to clinical reasoning (Fig. 1). The steps are as follows: consider the patient situation; collect cues/patient data; process information; identify problems/issues; establish

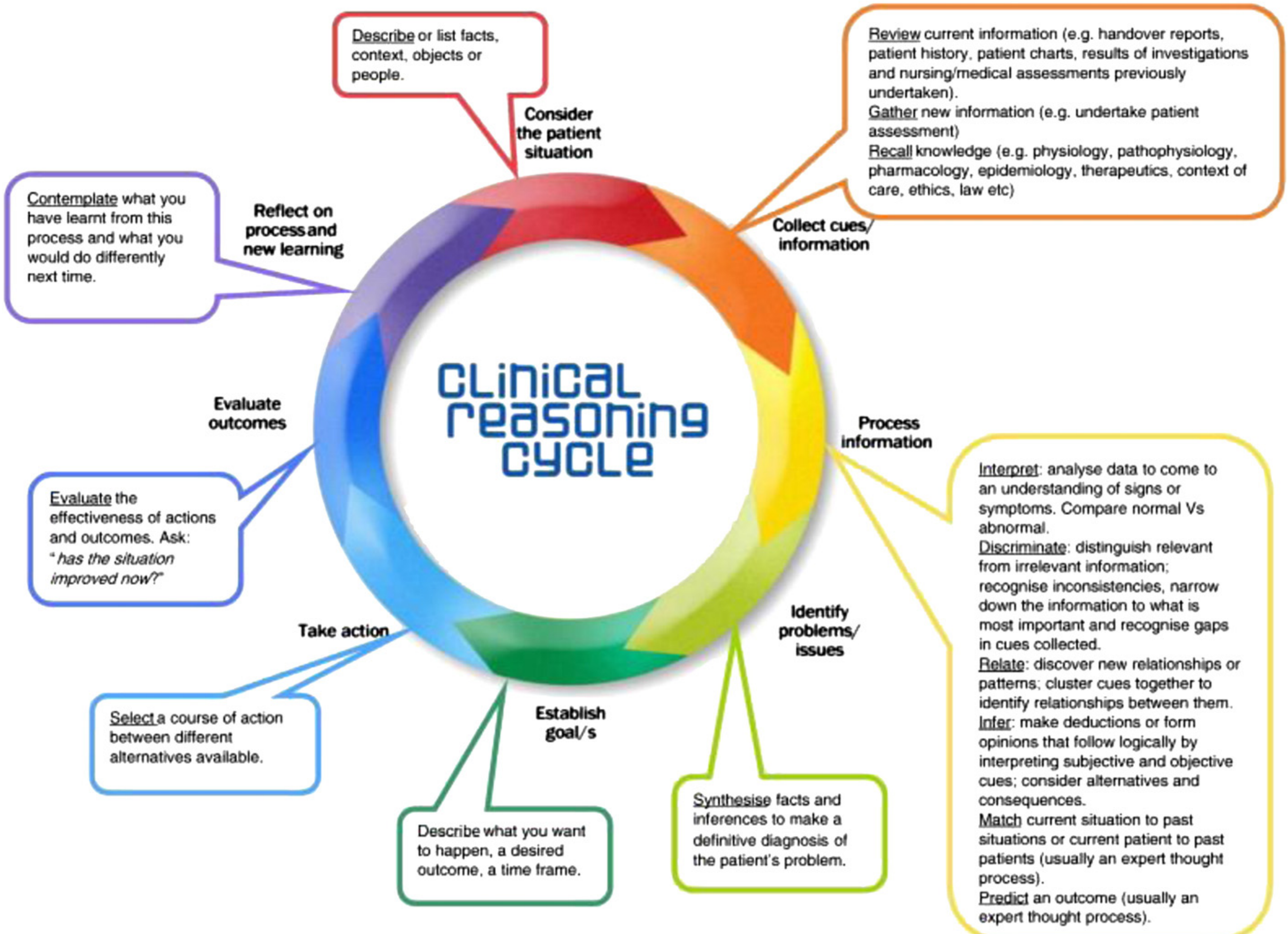

Fig. 1. Levett-Jones et al. (2010) Clinical Reasoning Model.

goals; take action; evaluate outcomes; and reflect on process and new learning. The CRC model is the model chosen to underpin the development of the Serious Game activities to be presented to learners as they navigate through the scenario because it offers an explicit clinical reasoning process that lends itself well to an authentic and immersive virtual design.

Serious Games as a Pedagogic Tool

New technologies are increasingly being integrated into health care curricula allowing students to develop new skills within a safe environment. Laboratory simulations with high fidelity mannequins, for example, have become an integral element in many health care curricula. A recent systematic review found evidence suggesting that the use of simulation mannequins significantly improved three outcomes integral to clinical reasoning: knowledge acquisition, critical thinking and the ability to identify deteriorating patients (Lapkin et al., 2010). Some regulatory boards (e.g. NMC in the UK) have even accepted a percentage of simulation hours as contributing towards the total number required for registration.

Yet Serious Games, a form of virtual simulation, are a relatively recent arrival in health care education, despite their long-standing presence in other fields such as aeronautics, nuclear testing and military war games. Whilst the term *Serious Game* has been loosely interpreted to mean almost anything involving technology, from interactive video simulation using cartoon animation (Kelly et al., 2007), to avatars (Knight et al., 2010; Thompson et al., 2010), to simply watching videos (Hummel et al., 2011); Serious Gaming is understood here to include: simulation, learning and game. The definition adopted for this project is "a pedagogical tool with a purpose, moving beyond entertainment to deliver engaging interactive media to support learning in its broadest sense" (De Freitas, 2006).

Serious Games offer immersive and virtual environments that provide students a realistic opportunity to practice and develop a variety of different competencies (Adams, 2010; Blakely et al., 2008; Rochmawati and Wiechula, 2010). Available on a computer terminal, Serious Games facilitate access and personalise the learning experience by offering a learning tool students can use anytime-anyplace (Kato, 2010; De Freitas, 2006). By providing a realistic environment, learning can advance beyond simple knowledge acquisition towards the development of skills necessary to recognise, analyse, select and apply knowledge to different clinical situations (Cook et al., 2010; Kiili, 2007). Such complex learning focuses on problem-solving, critical reasoning and meta-cognition (Gee, 2003).

Thus far Serious Games in health care education have emphasised the development of procedural techniques (Enochsson et al., 2004; Hagen et al., 2009), triaging skills in emergency situations (Knight et al., 2010) and resuscitation training following mass casualty disasters (Kurenov et al., 2009). To the author's knowledge there have only been two Serious Games designed for health care professionals outside an acute or critical care context: one for doctors in a home care setting (Duque et al., 2008) and the other for community health nurses (Hogan et al., 2007). More pedagogical tools of this type are need to provide authentic learning environment in which learners are able to practice the development of their cognitive processes and facilitate the detection of relevant cues and contextual issues to help them make connections between accurate cue collection, nursing interventions and patient outcomes in a variety of clinical settings.

Furthermore, few studies have explored the extent to which experiential simulation, such as Serious Games, can assist in the development of clinical reasoning (Charsky, 2010); and relatively little is known about methods for optimising the game design process (Hirumi and Stapleton, 2008). There is thus a need to create and evaluate a tool that will help enhance nurses' skills in reasoning clinically, detecting risk factors and intervening to prevent the worsening of a patient's chronic condition.

One Serious Game: Two Learning Objectives

One of the fundamental differences between Serious Games (SG) and other commercial video games is that the former are designed to facilitate the achievement of specific learning objectives. To develop a SG that meets anticipated pedagogical objectives, a "grounded design" is suggested (Hannafin et al., 1997). That is a "systematic implementation of processes and procedures that are rooted in established theory and research in human learning" (Hannafin et al., 1997, p. 102). This demands the application of a learning theory as well as coherent pedagogical approaches, whether these are influenced by the principles of behaviourism, cognitive information processing or constructivism (Gunter et al., 2007). The chosen learning theory determines the nature of the learning environment and guides the sequencing of critical learning interactions that are embedded into the Serious Game so the learners can meet the learning outcomes (Dick et al., 2011).

For the objectives of the Serious Game being developed for this project a constructivist learning theory is employed. This requires the learners to use various tools to access content information, derive meaning and construct knowledge of how to work through the scenario and solve the given problems. Guiding this construction of knowledge, Bloom's taxonomy offers six levels of competencies to acquire knowledge about a topic moving from simple to complex levels: Knowledge; Comprehension; Application; Analysis; Synthesis; and Evaluation (Bloom, 1956) (Table 1). Bloom's taxonomy provides a template for choosing appropriate pedagogical strategies according to the different levels of skills sought. To complement Bloom's taxonomy is Gagné's nine events of instruction that provides a framework for designing pedagogical environments aimed at stimulating the processes necessary for learning to take place effectively (Gagné, 1985). According to Gagné, employing these nine steps assures that the learner will have mastered the desired content and learning objectives, and thus facilitated the movement across Bloom's six levels of learning.

For the creation of the Serious Game scenario, Bloom's taxonomy and Gagné's nine instructional events are combined with Levett-Jones et al. (2010) model of the Clinical Reasoning Cycle to provide a methodological guide in the development of the pedagogical activities. These activities will be embedded in the storyline so as to move the learner towards the learning objectives of each level throughout the scenario. The two main learning objectives of the SG will be that: 1) the learner develops a systematic clinical reasoning approach based on the CRC model and that 2) the learner sharpens their detection, assessment and intervention skills in a home care/community context and becomes more aware of the consequences of their actions.

Table 1
Bloom's taxonomy.

Competency	Skills
Knowledge	Learner can recall information
Comprehension	Learner can explain and predict
Application	Learner can solve problems and use information
Analysis	Learner can see patterns or concepts and organisational structure may be understood
Synthesis	Learner can build a structure, put parts together to form a whole, with emphasis on creating a new meaning or structure
Evaluation	Learner can compare and make judgements about the value of ideas or materials

Inculcating a Clinical Reasoning Model

In the Serious Game scenario students will be providing care to a patient living with Type 2 diabetes. Such patients living with chronic illnesses (cancer, diabetes, cardiovascular disease) have been shown to generate more independent nursing judgements than surgical patients referred for treatments (such as wound care) (Fowler, 1997). Since nursing students need to be taught how to synthesise facts to make nursing diagnoses and select a course of action between different alternatives, a systematic approach is needed. Yet many nurses lack such a framework to help them confidently distinguish clinical noise from the clinical data that signals risk; a crucial factor in nursing errors (Levett-Jones et al., 2010; Thompson et al., 2008). The scenario will thus offer a number of visual cues, some more significant than others, allowing the students to practice choosing whether or not to act on them, and practice identifying patterns. The learners will be required to ask the right questions at the right time to obtain the relevant data regarding the patient's status and the environment. The Clinical Reasoning Model (Levett-Jones et al., 2010) will be embedded in the scenario offering a variety of exercises to trigger the learner to consider the different steps in the cycle. It is anticipated that it is through the interactions with the virtual patient and environment that the learner will begin to systematically apply the CRC model and practice prioritising interventions.

Recognising Action-Consequences

To meet the second objective, the Serious Game will allow students to observe the long-term consequences of their actions (or non-actions) by including a time-lapse functionality in the game. Students will visit their virtual patients in their homes and during community clinic visits and intervene according to assessments made over the course of "one year" which in real-time will span a few hours of gaming. The Serious Game scenario will be divided into patient appointments spread out over the period of twelve months (either at the patients' home or in the clinic) but these gaps of time will occur in accelerated time so the learner can apprehend how their decisions impacted their patient's health. Moreover, after each appointment the learner will have the opportunity to use available multimedia tools in the form of journal articles, electronic health records, and audio recordings of interviews with specialists, encouraging them to apply an interdisciplinary and evidence-based practice approach. Each appointment will have specific learning objective that will be met by completing a number of exercises. This opportunity to interact with the patient and the environment over a time-lapse year will allow the learner to apprehend how their ability to identify relevant cues and choose appropriate interventions impact the health and recovery of patients in the long term.

Serious Game Scenario Development

The creation of a Serious Game (SG) scenario is more complex than one developed for a classroom case study or a laboratory simulation. SGs do not follow a linear story-line but rather become a dynamic "metaplot" with the player participating in the unfolding sequence of problems, and this interaction with the game influencing the outcomes. In SG scenarios the learner can travel down an infinite number of paths that have been determined through the rules integrated into the game engine and which are meant to represent reality (Alessi and Trollip, 2001). Serious Games are unique in that they can be developed to have rules that can be broken or changed by the learner's action, differing from other types of video games which do not allow exceptions to the imposed rules and are thus better suited for achieving lower order thinking skills (Charsky, 2010).

As technology evolves it is increasingly possible to create game engines allowing even more flexible rule structures that facilitate higher order learning by integrated complex underlying models that allow for an untold number of outcomes. The advantage of such flexibility is that each time the learner plays the game the experience is unique because the flexible rule structure allows them to explore the game space, test hypotheses and fulfil goals in a variety of different, and sometimes, unanticipated ways (Charsky, 2010). They can learn more because there is no “right” way to play and many ways to succeed thus helping the learner develop flexible cognitive practices that can be applied to a variety of different real world situations (Koster, 2005; Spiro et al., 1995).

Like commercial video games, most SGs are broken up into levels that divide it into sections, organise its progression and enhance immersion in the game (Novak, 2011). Yet as previously mentioned SGs add a pedagogical component allowing the learner to progress to higher levels (increasingly more complex knowledge competencies) only once the lower level learning skills and competencies have been achieved. In this SG, these different levels will be the level of complexity with which the learner is faced at each patient appointment. If the learning objectives are met at the initial appointment, the learner then passes to the following level and the second appointment is more complex. However, if the learning objectives are not met the learner has a second appointment at the same level of difficulty whilst the patient's status continues to respond to the nursing interventions resulting in different outcomes over the course of each subsequent appointment.

Serious Game Engine Development

In medical contexts expert systems or knowledge-based systems have tended to be the most common type of artificial intelligence (AI) (Winstanley and Courvalin, 2011). These systems were first used in the mid-1960s when AI research focused on well-defined problems that could be solved using static underlying human expertise (Dhaliwal and Benbasat, 1996). The systems contained medical knowledge and could use data from individual patients, either real or virtual, to come up with conclusions about their health status. The use of medical expert systems increased in the 1990s through various applications such as clinical decision support systems. These were automated systems of embedded knowledge based on pre-determined links between patient signs, symptoms and pathologies to help clinicians reach diagnoses. Expert systems offer a number of advantages as they provide consistent answers for repetitive decisions, processes and tasks; can maintain a significant amount of information; and combine knowledge from many domain experts (Aniba et al., 2008). Yet they remain limited in their pedagogical ability to develop higher order thinking skills.

Newer expert systems have seen their rise in video game development, such as AI techniques (Rabin, 2002), and have allowed a drastic evolution in Serious Game information systems. These new systems link both video game engines with autonomous human expert knowledge bases, thus leading to “expert systems”. Fig. 2 illustrates the architecture of the Serious Game being developed for this project and is described in more detail below:

The Expert System

- The **knowledge base** (KB) contains the domain expertise and knowledge. It is represented in the form of facts and rules that the expert system uses to make determinations. A *static* facts base, obtained through the literature and health experts (Giuse et al., 1997), contains the necessary knowledge for understanding and formulating the problem under investigation. A *dynamic* facts base is used to collect the virtual patient's health data and keep track of the learner's actions throughout each game session (each appointment). The KB also has a set of rules (in the form of IF-THEN rules) representing pieces of knowledge and that results in a series of micro actions when the premises of the rule are fulfilled. Some of these rules use fuzzy logic to handle uncertainty and partial truth (Siler and Buckley, 2005).
- The **inference engine** interprets and triggers the rules in the knowledge base whenever the conditions are satisfied, deriving recommendations from the knowledge base and problem-specific data from the dynamic facts base and thus resulting in new facts.

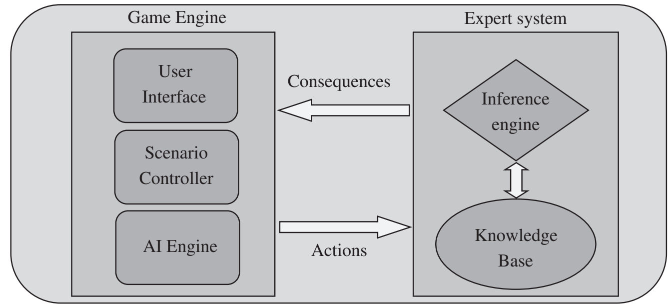

Fig. 2. Serious Game architecture.

The Game Engine

- The **user interface** controls the dialog between the user and the system and allows the student to interact in a virtual 3D environment. As input, the interface monitors the actions/interventions of the learner that are transmitted to the expert system and stored as new facts. As output, if these actions/interventions trigger any rule from the knowledge base that results in a change in the virtual patient's health status, the patient behavior and/or graphics is then updated.
- The purpose of the **scenario controller** is to initialise the game session; define its objectives; and update the objectives when they have been completed or become irrelevant. The controller collects data from the expert system's knowledge base to define and update the patient's health status and identifies the interventions the learner will be able to handle or perform throughout each session.
- The **AI game engine** interprets the consequences of the rules triggered by the expert system. Throughout the scenario, the system takes into account the time required for an expected response (e.g. to a medication or an intervention) and adapts it to the evolution of the scenario accordingly. This system is in constant link with the expert system and orders the sequence of subsequent events.

This interaction between the game engine and the expert system creates an innovative game mechanism. The SG enables access to all the actions relevant to the game context and does not guide the learner towards a specific course of action. Faced with an almost infinite variety of choices, the learner can experience the same scenario multiple times with different outcomes. The game engine uses rules and algorithms to create the artificial intelligence necessary for the game to respond to the learner's input. By applying rules that are data-driven and not dependent on the scenario's script a level of realism is added to the game.

Since a certain level of subjectivity is necessary to evaluate problem-solving and use of higher-order thinking skills, the final analysis of the learner's clinical reasoning skills will be assessed outside the game environment because "performance assessment using scoring rubrics…that describe different levels of proficiency is considered unsuitable for computer games…" (Mitchell and Savill-Smith, 2004, p. 50). Moreover, the descriptors required tend to be too imprecise for a computer to match specified criteria to students' behaviour (Leddo, 1996). Thus planned debriefing sessions will follow each appointment to explore the clinical reasoning process of the learners as they navigated through each session. The pathway against which students will be compared will be developed and validated using experts and following best-practice guidelines.

Conclusion

Changes in our health care system are demanding that nurses develop new skills and competencies. Advances in technology now allow educators to envisage new and innovative methods of preparing professionals for their evolving roles without putting patients at risk. Having the opportunity to 'test-out' various clinical reasoning pathways based on patients' signs and environmental cues allows the practitioner to become more aware of how they reason and recognise consequences of this reasoning on action. With limited opportunities to practice 'real-life' care outside of acute-care settings, Serious Games could become an important tool offering a safe, consistent and efficient learning experience for health care professionals.

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