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Evaluation of the Impact of Virtual Patient Systems on Clinical Reasoning and Student Assessment

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Abstract: *In contemporary times, medical education has extended into domain-specific educational activity that has become more digitized. This is as a result of the need for worldwide access to clinical skills development, higher clinical through put in academic teaching environments, societal push back to clinical practice on real patients and higher documentation requirements for procedural skills of all levels. Information and communication technology (ICT) in medical education has therefore advanced the development of interactive learning environments with immediate, content-related feedback which is a characteristic of virtual patient systems. Virtual patients (VPs) are interactive computer simulations of real-life clinical scenarios for the purpose of medical training, education and assessment. This work surveyed some existing virtual patient systems and results from the analysis of these systems by previous researchers were recorded. Mean score was computed for clinical reasoning and student assessment metrics and results show that virtual patient systems help medical students acquire clinical reasoning skills more efficiently and it is more effective in assessing these students than real patients.*

Keywords: *Virtual patient, student assessment, clinical reasoning, simulation, medical education.*

1.0 INTRODUCTION

In the last decade, the role of information technology and its benefits in the educational sector has become more obvious. In other to improve the educational process, e-Learning, active learning and virtual patient concepts are included in the university curricula [1]. Virtual patients are computer-based programs that simulate real-life clinical scenarios where learners emulate the roles of health care providers to obtain a history, conduct a physical exam, and make diagnostic and therapeutic decisions [2]. This software platform has become increasingly popular as a non-conventional teaching tool today especially in teaching clinical reasoning because medical education involves rich scientific terminology, large volumes of information in form of static images, use of human subjects in the training process, audio and video materials and accumulated experience in previous clinical challenges. Also, a shift to out-patient based care, minimization of hospitalization time, and shrinking of clinical revenues [3] has decreased the availability of good educational cases thereby hindering the students from practicing integrating knowledge. In addition, some patients are not suitable for students due to ethical considerations. However, the goal of the student is to find the right diagnosis and propose a correct medical treatment based on the data presented. VP systems enable medical trainees exert the role of a medical professional and support the development of clinical and decisional abilities [4] and it facilitates the learning process through an increased variability of the clinical cases accessible to the medical trainee. It also offers a controlled and safe environment in order to boost the confidence of the medical trainee’s clinical abilities [5]. VPs increase the effectiveness of learning by offering a simulated environment which closely resembles real situations which can be accomplished by creating an immersive effect using multimedia content and narrative scenarios. The first virtual patient systems emerged in the early 70’s and since then have evolved significantly, taking advantage of new possibilities offered by the Internet and multimedia technologies. Research shows that the systems enable students acquire clinical problem-solving skills more efficiently [6,7]. Moreover, the educational applications of VP systems are intimately connected to their design [8]. To reach the proposed learning goals most systems take advantage of the linear-interactive, branching or knowledge-based contextualisation layout. For example, Web-SP is a linear-interactive application [9], while Open Labyrinth has a branching layout. The users of VP systems are typically required to perform a variety of tasks, depending on the educational objective (find, solve, prevent, explore, critique, experience, collaborate, diagnose, treat). Medical students, however, suggest that the tasks should be authentic, allowing them to make all the “decisions a real doctor would make” [10]. It was stressed that despite the benefits of VP systems in medical education, it cannot replace traditional teaching because human interaction is still an important aspect of the learning process and cannot be simulated to an acceptable degree [11].

2.0 SIGNIFICANCE OF VIRTUAL PATIENT SYSTEMS IN HEALTHCARE EDUCATION

The need for higher clinical throughput in healthcare education, societal push back to clinical practice on real patients and higher documentation requirements for procedural skills of all levels are the original motivation for the creation of VPs [7]. VP systems allow for repetitive and deliberate practice of clinical skills by any student; nurses, doctors, dentists or pharmacists without regard to time of day, physical location, or position and provide practice in a safe environment with no risk to patient or student. It allows every student the opportunity to meet any disease they may encounter in their practice by providing cases optimized for medical education because some conditions are so rare, and it could take a lifetime to gain experience, while others that are common, are handled by the primary care and do not turn up at university hospitals [9]. Also, VPs provide an alternative method for students to interact with patients in a resource-, time and cost-effective manner. It enables students learn correct history-taking techniques prior to interacting with patients in the clinic and allow for repetitive and deliberate practice of clinical skills by students as they can learn their strengths and weaknesses in clinical reasoning with immediate performance feedback. In addition, medical educators can use virtual patients to create branched-narrative cases that engage student learning through decision points that have consequences affecting the patient, design cases using a Flash-based graphical user interface, track student performance metrics such as cost, time spent, and quality of care and exchange and adapt cases from other institutions using the MedBiquitous Virtual Patient XML data standard. Moreover, VP interactivity leverages Kolb and Fry's experiential learning theory, motivating the learner to actively participate in the educational process. By interacting with VPs under certain conditions, it is expected that learning will be more efficient and complete, with a higher retention rate over passive education approaches [11]. This Kolb and Fry's theory presents a cyclical model of learning, consisting of four stages, which tend to follow this sequence: concrete experience ("do"), reflective observation ("observe"), abstract conceptualization ("think"), and active experimentation ("plan"). Furthermore, virtual patients are discovered to be more standardized in teaching than human actors and may convey a significantly higher amount of didactic information [12] because the knowledge presented by these systems can be rapidly updated when it is necessary to do so, and it helps to understand large complex processes, in particular processes with strongly coupled influences and time dependent interactions. Lastly, by presenting clinical variations, VPs add to the general knowledge that a student can draw upon when confronted with a similar case, whether virtual or real, through pattern recognition [13].

3.0 SURVEY OF EXISTING VIRTUAL PATIENT SYSTEMS

A survey of existing VP systems was carried out in this research to determine the impact of VP systems on clinical reasoning and student assessment. The survey captures a general review of existing VP systems, method used for selected systems, results gotten from the evaluation of each system.

3.1 Review of Existing Virtual Patient Systems

A virtual patient (VP) system that enable learners interact with a life-sized avatar who presents with a medical complain via speech recognition and tracking systems was developed by [14]. The novelty of the system lies in the use of natural interaction and immersive virtual reality techniques. Students were able to interact with a life-sized VP due to the presence of speech recognition, natural language processing, body tracking systems, and a large screen or head-mounted display and through these inputs, is "aware" of the student. The technology that drives this interaction consists largely of commodity hardware and software; two desktop computers, two cameras, a data projector, and a wireless. Also, [15] developed a web-based VP system that enlists users for rapid and robust script development known as Virtual People Factory (VPF). The system concomitantly teaches students history-taking skills through the use of an Embodied Conversational Agent and an instant messaging program. It generates feedback which includes an Interview Transcript, a Topic Flow Outline, and a Topic Item Checklist ("discoveries") and students were able to converse with the VP in a question-and-answer format. Through this process, any script errors were identified by examiner, while making diagnostic and therapeutic decisions. The system also offered numerous advantages over traditional methods including: Standardized Instruction, Immediate and Objective Performance Feedback and Unlimited Opportunity for Repetitive Practice.

Moreover, a consortium of universities: University of Calgary, Queens University, Northern Ontario School of Medicine, Aristotle University Thessaloniki, St. George's University London and Karolinska Institute developed OpenLabyrinth an open-source system for authoring and playing virtual-patients. The software was extended to include additional features which enable authors to integrate and share virtual patient case metadata within the mEducator3.0 network. This improved OpenLabyrinth is known as Extended OpenLabyrinth (OLabX) which is a standalone Web distribution and Web interface software. OLabX was designed to semantically annotate virtual patients to facilitate intelligent searches, complex queries, and easy exchange between institutions. Its Evaluation include three successive steps: expert reviews, evaluation of the ability of health care professionals and medical students to create, share, and exchange virtual patients through specific scenarios in extended OpenLabyrinth (OLabX) and evaluation of the repurposed learning objects that emerged from the procedure [16]. Furthermore, in order to train students on how to care for refugee trauma patients, RTSim system was developed. The system creates realistic and engaging VP cases for Refugee Trauma in training students on refugee patient interview, used established trauma and mental health instruments as well as gives feedback to the learners. The patient interview section was based on video clips with a Bosnian actor which has a trauma story and mental health problems. The video clips were recorded in Bosnian language to further increase the realism, but also subtitled in English. The system was evaluated by 11 volunteering primary health clinicians at the Lynn Community Health Centre, Lynn, Massachusetts, USA. The participants were invited to provide insights or feedback about the system's usefulness and educational value. A mixed methodological approach was used, generating both quantitative and qualitative data [17].

More so, in order to develop nursing students' ability to translate and apply theoretical knowledge in a clinical context, virtual patient Nursing Model (vpNAM) was developed. The vpNAM builds on the 3rd generation nursing process and is composed of three main layers. Layer 1 focuses on patient-centric data collection, Layer 2 is about iterative clinical reasoning, and Layer 3 covers measurable outcomes. The developed design model reflects the nursing process (observation, assessment, nursing diagnosis, nursing prescription, planning, implementation, and evaluation) because it is recognized as a guideline for nurses in their clinical practice. The system serves as guideline for teachers when they create VPs and allow the systematic development of different types of virtual patients from a common model thereby creating opportunities for sharing pedagogical designs across technical solutions. Also, the model would provide a basis for research that builds on shared empirical findings and best practices [18]. In addition, Web-SP an interactive virtual patient simulator with a web-based user interface that offers an authoring tool was developed by the Karolinska Institute and offers the traditional functionality that is expected from a virtual patient simulation tool: patient history, clinical examination, laboratory tests, diagnostic, therapy, feedback and bibliographical references. The system was implemented in healthcare departments of more than ten universities around the world. Latest version includes features that increase the level of interactivity: free text search through medical history of the patient, improved physical examination, improved feedback [9]. Lastly, Oladosu *et al.* (2014) developed a web-based aboriginal virtual patient system for training indigenous Nigerian medical students. They were motivated by the fact that existing VP systems are foreign and therefore are unsuitable for training Nigerian medical students. The system was implemented in LAUTECH, Ogbomoso, Nigeria. The system was evaluated using questionnaire and results show that Web AVP is more effective in training indigenous Nigerian medical students than a foreign VP system. Also, students found the system more suitable in acquiring clinical reasoning skills and in assessing indigenous Nigerian medical students than real patients [19].

Table 1: Summary of existing VP systems

AUTHOR	SOFTWARE	USERS	TARGET AUDIENCE	DOMAIN
Deladisma, 2008	Life-Sized Avatar	Universities and medical institutions around the world	Undergraduate students	medicine
Hevil *et al*., 2009	Virtual People Factory (VPF)	Medical College of Georgia and the University of Florida	Undergraduate students	medicine
Dafli *et al*., 2013	Extended OpenLabyrinth (OLabX)	St George's, University of London, "Iuliu Hatieganu" U.M.Ph. Cluj Napoca, Northern Ontario School of Medicine, Aristotle University Thessaloniki, University of Calgary and University of Edinburgh	Undergraduate Students, post graduate students and teaching staff	all medical fields
George & Zary, 2014	vpNAM	Nursing schools around the world	Nursing students and teaching staff	Nursing
Zary *et al*., 2006	Web-SP	Universities and medical institutions around the world, e.g., Stanford	Undergraduate Students, post graduate students and teaching staff	medicine, dentistry, pharmacy
Oladosu *et al*., 2014	Web AVP	LAUTECH	Undergraduate Students and teaching staff	medicine
Ekblad *et al*.,2013	RTSim	Lynn Community Health Centre, Lynn, Massachusetts, USA	Undergraduate Students and teaching staff	medicine

3.2 Method

Seven existing virtual patient systems which include WEB SP, RTSim, Extended OPEN LABYRINTH (OLabX), Web AVP, VPF, vpNAM and Life-sized Avatar were investigated in this research. The sample size, method of data collection and analysis of each system by previous researchers were recorded.

3.2.1 Sample Size

Two hundred and eighty-three undergraduate students consisting of seventy medical students, one hundred and twenty-three dentistry students and ninety pharmacy students rated the performance of Web SP [9] while the evaluation of OLABX was carried out by ninety-eight participants [16]. Also, one hundred and ten participants consisting of eighty undergraduate medical students and thirty medical doctors were employed in rating the performance of Web AVP [19] while VPNAM was rated by one hundred and two undergraduate nursing students whose age ranged between 20-53 years with mean age of 23 years and gender distribution of 12.5% male and 87.5% female [18]. In addition, fifty-one first-year medical students and twenty-three third year medical students participated in rating the performance of VPF and LIFE-SIZED AVATAR respectively [15,14] while RTSim was evaluated by eleven participants [17].

3.2.2 Data collection

The method used by previous researchers in collecting data for the selected systems is shown in table 2. Extended Open Labyrinth, Web SP and Web AVP employed expert interview and expert reviewers comment [16,9,19] while Life Sized Avatar and VPF used student interviews [14,15]. vpNAM used questionnaire alone [18] and RTsim employed questionnaire with interview [17]. The methods used by each researcher to analyse the systems were recorded as shown in table 3. Life sized avatar employed Fischer's exact test (α =0.05) while VPF used Bar Chart. Web AVP used bar charts and T-test comparison and Web SP used Descriptive Statistics with Median values (p25 – p75) and Bar Chart. Extended open Labyrinth used percentile rank while VpNAM used Descriptive Statistics.

Table 2: Methods used in evaluating and analysing each VP system

S/N	SOFTWARE	DATA COLLECTION METHOD	ANALYSIS METHOD
1	Life-Sized Avatar	Interview	Fischer's exact test (α =0.05).
2	Virtual People Factory (VPF)	Interview	Bar Chart
3	Extended OpenLabyrinth (OLabX)	Testing scenarios, Questionnaire and expert reviews	Percentile rank
4	vpNAM	Questionnaire	Descriptive Statistics
5	Web-SP	Questionnaire and expert reviews	Descriptive Statistics (Median values (p25 – p75)), Bar Chart
6	RTSim	Questionnaire and expert interview	Descriptive Statistics
7	Web AVP	Questionnaire and expert reviews	Bar charts and T-test comparison

4.0 RESULTS AND DISCUSSION

Results from the analysis of the selected VP systems by previous researchers were recorded in table 3. Using descriptive statistics, RTSim was evaluated and the overall result for student assessment and clinical reasoning were 80.0 percent and 63.1 percent respectively. Also, vpNAM was evaluated using descriptive statistics and the overall result for student assessment, clinical reasoning skills and perceived usefulness are 52.5 percent, 70.0 percent and 45.5 percent respectively. Moreover, the overall result from evaluation of RTsim yields 80.5 percent, 72.5 percent and 76.5 precent for student assessment, clinical reasoning skills and user's perceived usefulness parameters respectively. Furthermore, evaluation of Extended Open Labyrinth revealed that the system has 63.5 percent rating on user's perceived usefulness. In addition, results of perceived usefulness and clinical reasoning metrics for Web AVP system are 57.3 percent and 55.5 percent respectively. Moreso, results recorded by previous researchers for Virtual People Factory (VPF) system show that student assessment, clinical reasoning skills, user's perceived usefulness and authenticity metrics have 61.0 percent, 65.0 percent, 73.9 percent and 78.3 percent respectively. Finally, results from evaluation of Web-SP show that clinical reasoning, ease of use and authenticity metrics are: 75.0, 79.2, 79.2 percent respectively.

Table 3: Results from evaluation of existing VP systems

VIRTUAL PATIENT SYSTEMS	CRITERIA			
	STUDENT ASSESSMENT (%)	CLINICAL REASONING SKILL (%)	EASE OF USE (%)	AUTHENTICITY (%)
LIFE-SIZED AVATAR	61.0	65.0	73.9	78.3
VPF	80.5	72.5	76.5	------
WEB SP	-------	75.0	79.3	79.2
VP Nursing Model	52.5	74	------	45.0
OLabX	69.0	75.0	63.3	89.5
RTSim	80.0	63.3	-----	-------
WEB AVP	-------	50.2	50.0	--------

This research determined the impact of Virtual patient systems on clinical reasoning and student assessment by first extracting the percentage score for each system recorded by previous researchers as shown in table 3 and calculating the mean score of the two metrics: clinical reasoning and student assessment. In determining the impact of VP systems on student assessment, the mean score of five selected systems which include: life sized avatar, VPF, VPNAM, OLabX and RTSim was calculated and 68. 6 percent was gotten. Also, the impact of VP systems on clinical reasoning was determined by computing the mean score of the seven selected VP systems and 67.86 percent was gotten.

5.0 CONCLUSION

Virtual patient systems are known as non-conventional teaching tools in healthcare education because they increase the effectiveness of learning by offering a simulated environment which closely resembles real situations. This paper reviews seven existing VP systems and results show that the systems enhance health care education greatly especially in clinical reasoning and student assessment. Therefore, it is recommended that VP systems be incorporated into the university curricular as part of teaching aid to students and implemented in underdeveloped countries so as to advance healthcare education globally.

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