

COMPARATIVE STUDY OF VIRTUAL PATIENT APPLICATIONS

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It has become more obvious over the last decade that the information technology has an increasing role in education, bringing along a series of undeniable benefits. This changes and diversifies the ways of teaching as well as those of learning. Medical training is one of the fields that can greatly benefit from these new learning methods. Concepts as e-Learning, active learning and virtual patient are increasingly present in university projects, university curricula or in health institutions having as final goal the improvement of the educational process. This paper investigates the current state in the field of virtual patient platforms and compares important features that make them valuable tools for enhancing performance in medical education.

Key words: e-learning, teaching, learning, medical education, virtual patient, multimedia.

1. INTRODUCTION

Having the results of Bloom's research [1] as a starting point, Anderson & Krathwohl [2] propose a revised classification of learning related cognitive processes: (a) knowledge retrieval, (b) comprehension, (c) application, (d) analysis, (e) evaluation, (f) creation. Bloom established that most student assessment methods were only addressing the first level, knowledge retrieval. However a complete learning process must build abilities on all six levels. Computer Assisted Learning (CAL) is a valuable tool that responds to these requirements preparing students for problems they will encounter in real-life by using complex simulations of realistic situations.

In Romania, according to the Romanian College of Physicians, the healthcare sector has a deficit of 40% in the number of healthcare professionals. At the same time it is affected by a chronic lack of funds and struggles to cope with the large number of patients that request medical services. To complete the picture, the academic domain gradually lost its attractiveness mainly because of the low wages, high demands and precarious working conditions. Under the circumstances the educational process is also impaired. An enhanced individual study could at least partly compensate these shortcomings by using new technology supported learning methods. Promoting individual study or learning in small groups improves performance of future medical professionals which is beneficial to the social and to the economic environment.

Medical education has some particularities: rich scientific terminology, large volumes of information in form of static images, audio and video materials, the importance of accumulated experience in previous clinical challenges, use of human subjects in the training process, etc. As stated in [3] “Traditionally, medical education had as its foundation a combination of didactic instruction in the classroom and integrated, hands-on *Socratic Method* learning in the clinical setting”. This is why Case-Based Learning (CBL) and Project-Based Learning (PBL) are learning paradigms that gain popularity by involving the trainee in complex and interesting activities that stimulate the learning process. They encourage collaboration on solving various problems, decision taking and research. Studies like [4, 5] and [6] show that medical staff that did PBL training stages had increased abilities in solving clinical problems.

Computer Assisted Learning as part of the e-Learning is a training method centered on using computer software. By interacting with the application the trainee engages a series of activities that support the learning process. This is achieved by helping the trainee to understand the connections between various elements and by stimulating the memorization for a long duration. Furthermore due to a computerized environment, the level of interactivity is much higher compared to the classical learning paradigm based on student-professor interaction. Text, images, audio and video sequences represent multiple channels through which information is passed to the trainee.

One of the most modern and efficient computer assisted learning methods uses the *virtual patient* concept (VP). This concept encompasses the interactive computer simulations used in medical education which are focused on simulating the clinical stages: history taking, physical examination, ordering laboratory tests, establishing the diagnostic, prescribing the therapy, getting the feedback. Creating VPs requires scientific excellence, modern technologies and is based on the *Game Based Learning* concept. VP applications allow trainees to exert the role of a medical professional and support the development of clinical and decisional abilities [7]. This kind of software is gaining popularity as it facilitates the learning process through an increased variability of the clinical cases accessible to the trainee but also by offering a controlled and safe environment which can boost the confidence of the trainee in its own clinical abilities [8].

This paper focuses on getting an overview picture of the most popular virtual patient software currently available, through comparative analysis. It is by no means the purpose of this paper to establish a ranking of these software products, but to determine the current state and the direction of development in this field. To this end the following specific issues will be approached:

- establish the criteria for comparative analysis;
- select virtual patient products to be included in the study;
- acquire information according to the proposed criteria;
- analyze acquired information by pointing out common features and differences;
- comment on the results.

2. MATERIALS AND METHOD

2.1. Assessment criteria

For the comparative analysis, three categories of criteria were considered: target, functional and technical. The first category looks at the current users of various virtual patient software and at the specific domain that the software targets (medicine, pharmacy, dental medicine, other). The second category concentrates on the application usage and features that are important from the user perspective, both author and trainee, while the third category encompasses technical aspects of the software product. Based on the mentioned categories, the following criteria were taken into account.

Table 1

Criteria for virtual patient platform assessment

Target	Functional criteria	Technical criteria
<ul style="list-style-type: none"> • current users • target audience • domain 	<ul style="list-style-type: none"> • structure • multimedia content • import/export capability • metrics available • VPs deliverable on mobile devices 	<ul style="list-style-type: none"> • platform • operating system (client and server) • programming language • license type

2.2. Virtual patient software selection

We conducted a research using Internet sources and scientific papers to determine the virtual patient software systems to be considered in this study. The MedBiquitous Consortium develops information technology standards for the healthcare domain. The list of the MedBiquitous Virtual Patient Standard implementers can be found in [9]. Besides these, other virtual patient systems were also taken into account considering their user base and their visibility in the media. Adoption by universities and inclusion in their

healthcare curricula was also a considered aspect. The eViP, a European effort to build a database of 320 virtual patients also mentions the most important platforms currently in use.

Based on the assessment criteria (Table 1), an analysis of the common traits and differences of the virtual patient platforms will be performed. Most important characteristics will be pointed out and the trend in the development and usage scenarios of these platforms will be discussed.

2.3. Short description of the analyzed software platforms

1. **vpSim** is a software product which was developed starting with 2007 by the *Laboratory for Educational Technology, University Of Pittsburgh School Of Medicine* for the computer simulation of clinical cases. **DecisionSim** is a commercial version based on vpSim, built by the Decision Simulation company beginning with 2010 [7]. In these applications, the student plays the role of a medical professional that interacts with a virtual patient through the computer screen. The actions of the medical professional are typically the following: patient interview, physical examination, prescribing tests, establishing the diagnosis and establishing the therapeutic algorithm.

2. **MedSims** is a software platform initially created by TheraSim and currently developed by WebMD with the purpose of improving the educational process through the use of virtual patients. MedSims presents realistic clinical scenarios that can be approached by the trainee in a risk-free virtual environment. The platform incorporates the National Committee for Quality Assurance's (NCQA) formula for improvement: Measure, Analyze, Improve, and Repeat. Among novel features, the artificial intelligence simulates more than one million clinical decisions. Free CME resources including virtual patients for various medical specialties are available at [10].

3. **Web-SP** is an interactive virtual patient simulator with a web-based user interface that offers also an authoring tool. The software system 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 [11]. Web-SP is 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.

4. The **CAMPUS** software was created by the University of Heidelberg Germany as an interactive case based multimedia learning system. Real life clinical scenarios are simulated covering all the steps: patient history, diagnosis and therapy. The system provides feedback for each decision of the user. CAMPUS offers several work scenarios: authoring tool, linear case presentations, knowledge evaluation module [12]. The linear card based structure is well suited to preclinical and CME. When authoring a virtual patient, a pre-built template can be used. Interactive images as a useful means of knowledge transfer can be produced even by unexperienced users and can be included in the developed virtual patients.

5. **OpenLabyrinth** is an open-source system for authoring and playing virtual-patients [13]. It is developed and maintained by 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. The software can be installed on servers running on Linux or Windows Server operating system and requires a web server with Apache, a MySQL database engine and PHP. LAMP or WAMP preconfigured servers allow a fast installation of all these required components. OpenLabyrinth can be used as an assessment tool due to its detailed metrics which are built into the server. The virtual patients can contain any type of media and can be used for both teaching and assessment activities. Also instead of running the virtual patient cases in OpenLabyrinth these can be accessed by communicating with the web services that OpenLabyrinth provides. In this way a custom user interface can be developed that works with the OpenLabyrinth engine in the backstage. The OpenLabyrinth project is actively developed, currently version 3.2 (12.08.2014) being the latest release. A demo is available at [14].

6. **OpenTUSK** is a platform built on the foundation of a content management system designed to manage several aspects of teaching in health sciences schools: curriculum, courses, content, clinical teaching, personalized knowledge, student data and faculty enrollment. The clinical teaching features a virtual patient builder which can be used to create interactive exercises for presenting clinical cases. The usual activities are simulated: performing physical examination, ordering tests, creating differential diagnostics, etc. [15]

7. **CASUS** is a case-based, multimedia learning and authoring system developed by Instruct AG, Germany based on the linear or string of pearls structure. The platform features several modules: Authoring System, Learning System, Course Manager, ExamTool, Evaluations and mLearning. The CASUS system can be easily integrated with popular learning management systems (Moodle, ILIAS, CLIX). Demonstrative cases can be found in [16]. Until 2010 more than 1000 cases [17] have been created and deployed to various educational institutions.

Information according the criteria in Table 1, acquired for all virtual patient platforms, is presented comparatively in Tables 2–4.

Table 2

Targets of virtual patient platforms

No.	Software	Users	Target audience	Domain
1	vpSim	UK: St Georges Univ. of London, Warwick University, University of the West. US: Northwestern University, Cleveland Clinic, University of Pittsburgh	all education levels and content domains but optimized for healthcare	medicine, pharmacy, dentistry
2	MedSims	US universities and medical institutions	students and teaching staff from medical fields	medicine and pharmacy
3	Web-SP	Universities and medical institutions around the world, e.g. Stanford [18]	undergraduate students, postgraduate students, CME	medicine, dentistry, pharmacy
4	CAMPUS	Universities from Germany, Netherlands, Bosnia and Herzegovina, Romania	all	all medical fields
5	Open Labyrinth	St George's, University of London [19], "Iuliu Hatieganu" U.M.Ph. Cluj Napoca, Northern Ontario School of Medicine, Aristotle University Thessaloniki, University of Calgary [20], University of Edinburgh [21]	undergraduate students, postgraduate students, CME	all medical fields
6	OpenTUSK	Medical, dental and veterinary schools at Tufts University and other users in the US, Africa and India [15]	undergraduate students, postgraduate students, CME, schools	medicine, dentistry, veterinary medicine
7	CASUS	Med-U [22], NetWorm [23], other universities and virtual universities in Europe (medical schools, dental schools, veterinary schools and CME)	undergraduate students, postgraduate students, CME, law schools	medicine, dentistry, veterinary medicine

Table 3

Functional characteristics of virtual patient platforms

No.	Software	Structure	Multimedia content	Import/ export in MedBiq std. format	Metrics	Mobile
1	vpSim	linear and branched	yes	yes	yes	yes
2	MedSims	linear and branched	yes	no	yes, using complex metrics for assessment	yes
3	Web-SP	linear	yes	yes	yes, through the exam module	yes
4	CAMPUS	linear	yes	yes	yes	yes
5	Open Labyrinth	linear and branched	yes	yes	yes	yes
6	OpenTUSK	linear and branched	yes	yes	no	yes
7	CASUS	linear	yes	yes	yes, with the evaluation modules	yes

Table 4

Technical characteristics of virtual patient platforms

No.	Software	Platform	Server OS	Programming language	License type
1	vpSim	web application	Windows Server	ASP.NET, Flash	annual license
2	MedSims	web application	Linux	PHP	limited access with user account
3	Web-SP	web application	Unix/Linux/Win/Mac OS X	Java	limited access with user account
4	CAMPUS	web application	not available	not available	commercial or free for educational partners
5	Open Labyrinth	web application	Windows, Linux, MacOS (LAMP, WAMP)	PHP	open source (GNU General Public License)
6	OpenTUSK	web application	Linux	Perl	Educational Community License, Version 2.0 (ECL-2.0)
7	CASUS	web application	not available	not available	license fee issued by Instruct AG

3. RESULTS AND DISCUSSIONS

All software platforms included in this study are state of the art tools capable of revolutionizing medical education. The advances in computer technology, both in software and hardware and the ubiquity of Internet access create a strong foundation for delivering new learning technologies closer to the users. As Table 4 shows, all Virtual Patient platforms share an important feature: they have been developed as web applications. Local, offline content distribution on CD-ROM or DVD-ROM is a thing of the past. This means that an Internet connection is required but at the same time a number of important advantages emerge:

- widespread availability eliminating the need of being present in a classroom;
- compatibility with mobile devices (Table 3);
- no installation required on the client side;
- simplified update, upgrade or patching procedures as these affect only the centralized server-based installation.

The software technologies used to build these software products are currently the most popular in the field. ASP.NET was used for server side programming in the Windows Server based platform vpSim. Some platforms, on the other hand, are Linux based, which confirms the trend in the field of enterprise applications. Linux is now leading the server market due to its performance and security characteristics and this is also the reason it was selected for the rest of the analyzed platforms. Having Linux as the operating system, programming languages like PHP, Java and Perl have been employed being popular for their stability and performance.

Looking at the current user base it becomes clear that this type of new learning technologies have gained acceptance in prestigious universities around the world. They are used as a way of enriching the traditional learning methods and are included in the faculty curricula. The adoption process is not a simple task and requires a sustained effort for interfacing with the classical teaching paradigms and for constantly enhancing the virtual patient collection both in number and in subject coverage. In terms of targeted audience, the analyzed platforms can cover all educational levels: undergraduate students, postgraduate students, continuing medical education (CME). Some platforms have been successfully applied to other fields like veterinary medicine or law school (see CASUS).

Regarding the structure of the underlying clinical case, some platforms can author and play only linear virtual patient systems (Web-SP, CAMPUS, and CASUS) while other support both linear and branched models (OpenLabyrinth, vpSim, MedSims and OpenTUSK). [17] states that linear models are easier to implement and to understand which accounts for their spread in the virtual patient community. However only

branched systems can allow the trainee to get feedback about the consequences of their decisions in a realistic way [24].

Multimedia content capabilities are present in all platforms as they are a key feature in modern e-learning platforms. Presenting information on multiple channels to the trainee not only stimulates interest in interacting with the software but also improves the learning process itself. Students that have undergone learning stages where multimedia content was involved achieved better performance later and had a greater satisfaction in learning [25, 26]. The analyzed platforms can use a variety of content types: various document types, static images, audio sequences, video files and even YouTube content (*e.g.* OpenLabyrinth).

Due to the fact that creating virtual patients is a laborious and costly process, sharing them becomes an important issue that contributes to the number of virtual patients available to users. The MedBiquitous initiative set out to create standards that will enable the exchange of virtual patients across systems and institutions. Currently most of the platforms (Table 3) implement the MedBiquitous virtual patient standards.

Counters are useful features in assessing the quality of the learning process. Education metrics standards [27] create a common platform for exchanging virtual patients as assessment tools. Except OpenTUSK for which we couldn't find any reference relating to metrics, all other analyzed platforms contain counter functionality either built-in or as a part of the assessment module. In advanced metrics modules, counters can be work together with rules that specify various actions if the counter value meets satisfied some criterion [28].

Concerning the operating systems and the software technologies used for development, two categories have been recorded. For the platform targeting the Windows Server, the ASP.NET language has been employed for the server side programming and AJAX, CSS, HTML and jQuery for the client side development. On the other side most virtual patient platforms, as shown in Table 4, are Linux based. This is justified by its performance and security characteristics which drives the increasing popularity of this operating system in enterprise applications. The programming languages were in this case: Java, PHP and Perl. These facts show that developers are taking into account the current trend towards mobile applications deliverable on a wide range of devices and preferred by many young people. The same reason switched the decision to web applications that are cross-platform, involve a very thin client, namely any web-browser and centralize the core functionality on a server, thereby greatly simplifying management.

An important aspect when planning the implementation of such a platform, especially when the university or institution in question does not have the necessary finances at its disposal, is the licensing type. Two of the seven popular platforms presented in this paper, OpenLabyrinth and OpenTUSK, have been licensed as open source software which grants free usage and opens the code to community contributions. Both are actively developed and new versions are published periodically. The fact that they are open source does not imply a short list of features or lack of reliability. On the contrary these two products are very rich in functionality and the active developer community behind them is a guarantee for reliability and constant maintenance. They are already implemented in prestigious universities and in production for several years.

Commercial software brings the advantage of carefully designed user interface and increased user friendliness. Licenses are available for universities or for institutions that are active in the healthcare sector.

4. CONCLUSION

Virtual patient software platforms are becoming increasingly popular as non-conventional teaching tools especially when it comes to teaching clinical reasoning. These new methods increase the effectiveness of learning by offering a simulated environment which closely resembles real situations. This can be accomplished by creating an immersive effect using multimedia content and narrative scenarios. Nevertheless the new virtual patient paradigm cannot replace traditional teaching, as human interaction is still an important aspect of the learning process and cannot be yet simulated to an acceptable degree.

In healthcare institutions where the budget does not allow the purchase of a virtual patient platform, open source alternatives are available. Installation of these platforms is not straightforward but can be accomplished by an IT department and does not require costly hardware investments. In this way new learning technologies can be implemented in underdeveloped countries contributing to the advance of the healthcare domain in those countries.

Considering that users who interact with virtual patient software are not IT specialists, the analyzed platforms have made good progress in providing a simple to use and intuitive interface. However we consider that improvements are still necessary, especially when the creation of complex structures is targeted. This could be achieved by offering advanced templates that could simplify the creation of this type of cases.

Looking at known examples of virtual patient platform implementations the large majority of them are situated in the medical education area. However, due to its graph structure and the multimedia content, many more fields could benefit from this technology, especially where decisions are a key factor of the specific activities.

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