Virtual Patient Simulator for Skill Training in Dentistry: A Review

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Abstract—Diagnostic errors represent a significant source of harm throughout the healthcare profession. Similarly, in dentistry, these could lead to missed diagnoses, wrong or unnecessary therapies, loss of patient's trust, and even the loss of the life of a patient. Therefore, it is important to improve the education of future healthcare professionals by optimizing their cognitive and practical skills by minimizing or avoiding errors that can happen during skill training. For this, virtual simulators are introduced as a further step to help students grow and advance the required clinical skills in a representative virtual environment. This is supported with the educational approaches such as problem-based learning with an increased amount of guided practice at a relatively low cost. These models encourage students to practice problem-solving skills individually with the involvement of many forms of media and materials that stimulate students' interest in learning and result in higher satisfaction. Current implementations mostly include virtual patient simulators with different approaches as haptic-based, web-based, etc. This survey is based on the development of such Virtual Patient Simulators for dental students including intelligent tutoring systems for improving decision-making skills in dentistry. It aims to provide a comparison about the specific features with virtual reality in the dentistry field.

Index Terms—problem-based learning, dentistry, virtual patients, game engines, virtual simulation.

1 Introduction

During the last two decades, information and computer technologies have had a considerable impact in general as well as in education. Together with other educational sectors, dental education generally has also started to use a blend of different teaching methodologies for their students. But much of the teaching of skill training, clinical problem solving and therapy planning have traditionally been undertaken during clinical courses while students attend their clinical sessions [1]. Paper-based educational systems have been used for many years to enable students to self-assess their clinical reasoning abilities. Even the feedback was only provided for certain scenarios when presented during scheduled case seminars.

But, in the process of becoming professionals, the students have to improve their skills to meet satisfactory levels. For this, appropriate patient assessment is a basic skill that would be required in any clinical discipline. It includes proper history taking, adequate examination of the patient and the decision on the required investigations. Therefore, the need for appropriate patient assessment and proper clinical reasoning methods has become one of the main necessities for dental students [2]. In addition to that, adequate training in problem-based decision-making of students has been identified as another area that needs to be improved. Also, because of the fewer chances for a real-time tutoring system to improve skill training, it has not motivated the students to improve their skill training and decision-making in their clinical sessions.

As a solution for this, effective computer-assisted learning in undergraduate clinical dental programmes has been identified, as it can be used as an adjunct to traditional education or as a means of self-instruction. Computer-assisted learning will benefit the students in self-paced and self-directed learning with increased motivation [3]. However, dentistry has used computer-assisted learning systems and various applications that are aimed at presenting patient cases and/or demonstrating certain practical tasks since the 1980s. One such example is virtual patient (VP) systems [4].

VPs defined as "interactive computer simulations of real-life clinical scenarios for the purpose of healthcare and medical training, education or assessment" [4], [5]. Thus now they have become one of the most commonly used Case-based learning or Problem based learning types [6] in modern medical education [7]. These are interactive computer programs that simulate real-life clinical scenarios in which the student acts as a healthcare professional. In these scenarios, the student obtains a history, performs physical examinations, orders and interprets lab and/or imaging tests and finally makes diagnostic and therapeutic decisions. Also, it enables training on diagnostic reasoning and systematic patient approach and treatment, resulting in a comprehensive treatment plan before actually treating the virtual patient in the simulator.

VP skill training mainly focuses on the assessment process of the dental students by providing more information that can be used to improve the treatment outcome than one can get directly from the patient. It will mainly contain structured, actual and concrete information and are more likely to contain exam-relevant material. Since students usually adopt a learning strategy which focuses on the exam results when studying, they might be more motivated to use the application if it is related to what is going to be assessed in the exam or else the system can be itself used as an evaluation process.

In the specific field of dentistry, some works investigate the use of VPs using different approaches. While several implementations have used problem-based learning, there can be identified studies that integrate with AI. Haptic device-based sImulating systems and exam-focused evaluation systems are some other aspects that have been already considered. This review paper is an overview of such studies and identifies the areas that can be further improved in virtual simulators for skill training in dentistry.

2 PROBLEM-BASED LEARNING

Virtual patient skill training often uses problem-based learning approaches to train students [8]. In problem-based learning (PBL), students learn about a subject by attempting to solve an open-ended problem. PBL is a student-centered approach. PBL is also an active way for students to learn basic problem-solving skills and acquire knowledge through interaction with others, a key skill demanded by nearly every work environment. PBL [9] is intended to test students' knowledge and help them develop their clinical reasoning abilities by presenting real-world patient problems as challenges.

The learning in PBL is driven by the problem. In medical PBL settings, students are exposed to "real-life" scenarios that call for collaborative problem definition, hypothesis generation, data collection and analysis, and evaluation or justification of solutions [10]. The patient's problem is designed to challenge students to develop reasoning, problem-solving, and team skills. The creation of solutions for the issue is actively involved by the students. As they come across the problem, they arrange and integrate the information they've learned. The challenge acts as a stimulus for learning, information recall, and knowledge application.

Although PBL has numerous advantages, it also requires a high level of personal attention from the tutor in order to identify when and where the students most need assistance and to assist them in discovering their own solutions [9]. Giving such attention becomes more challenging in the current academic environment when resources are becoming more scarce and expenses must be reduced. This is made worse by the fact that teachers, especially in medical schools, frequently have limited time on their hands to teach. Medical students therefore often do not receive as much aided PBL training as they may want or desire.

However, PBL has been identified as a significant approach in different types of fields. Especially in the medical sector PBL can be selected as one of the key factors that should be applied in a virtual training environment.

2.1 PBL in medical education

Traditional paper-based cases are linear so that the students can learn only in one direction. Because of that, they cannot work on their own decisions to experience the consequences of their own activities. They can only work on the path mentioned in the paper. This will limit the development of students' clinical understanding and competency or reasoning. Also, there is a gap between real-life situations as in real life, there are thousands of ways to have a problem or to make mistakes by the students. So overall the "paper" case is not very effective since it will not give an opportunity for students to control the scenario or manage the patient by themselves. Therefore PBL approaches have been mainly encouraged in medical education as it helps to improve the decision-making skills of the students.

As [11] mentions, modern PBL development mainly looks into the possibility of more interesting ways to present the relevant cases using interactive, visually oriented technologies. This need was highlighted during the time of COVID-19 pandemic in 2020 since much of medical education moved to virtual platforms in a very short time.

St George's University of London follows PBL cases that include branching points. They allow students to choose different actions or interpretations. As a result, the students can experience the good and bad sides of their decisions. It is similar to real-life situations attached by cognitive learning theories which focus on linear problem solving and the importance of grabbing the right outcome [12]. In the virtual world [11], PBL cases allow safe practice while exposing to rare diseases or conditions and improving the decision-making skills of the students [13], [14].

Also, several researchers [15], [16] have proved that the students who have the PBL practice, have better performance in examinations than the students who haven't experienced it. So, virtual training platforms with PBL are much beneficial in student-activated learning in medical education.

3 EXISTING IMPLEMENTATIONS

3.1 Virtual haptic-based simulators

When considering virtual simulators in dentistry, several studies [17], [18] have considered implementing haptic-based virtual simulators. Although having good visual aids including 3D images provides an improved understanding of the students, still there is an imperfection without the tactile sensations. By using textual or verbal descriptions, tutors may not be able to provide accurate tactile sensations to the students. As a result, haptic-based simulators have been introduced as a solution. This will present a better measurement of the students' performance while giving experiences very similar to real situations. Mainly these systems target practising clinical skills of the students. According to studies [4], they are cost-effective, require less maintenance, and do not require to replace the haptic devices frequently.

3.1.1 DentSim

One of the haptic-based simulators is the DentSim system [19]. It is a computer-assisted dental simulator that provides simultaneous visual, audio and practical inputs for learning. As a haptic device, it contains a handpiece and a phantom head with an optical tracking camera. The motions made in the phantom head will send to the computer display. This helps to evaluate the student's progress in the actual tooth preparation such as handpiece positioning, depth, wall angle, retention, etc. Feedback from the system is displayed on the screen. This simulator makes intra-oral activities effective. Further, it reduces the time and cost needed in conventional clinical training.

3.1.2 MOOG Simodont Dental Trainer

The primary difference between MOOG Simodont Dental Trainer and the DentSim is that MOOG Simodont Dental Trainer does not contain a physical phantom head. It contains a display projecting the mouth and tooth of the VP as a stereo image on a mirror. The mirror is above the headpiece. The system provides tactile feedback to the student by vibrating or generating a counterforce to the student's movement. Like in real scenarios, the student can apply a physical drill handle by wearing stereoscopic glasses, and spatial illusions. Also, the drill handle can generate haptic feedback depending on the virtually prepared material. (e.g., enamel, dentin, or pul) . So by different techniques, the system tries to give tactile feedback as much as possible.

3.1.3 PerioSim haptics

Another system is PerioSim haptics [17]. The specialty is that it can be done in periodontal procedures. The system contains a high-performance PC, graphic card, and stereo glasses for 3D visualization. It mainly focuses on developing the ability to examine the subgingival surface, handle gingival tissues, or perform scaling and root planing. For that, 3D visualization of the human mouth is displayed on the screen.

3.2 Virtual reality training simulator in tooth preparation practice

Virtual reality training simulator (VRTS) [20] in tooth preparation practice is a haptic-based system that is developed with Unity 3D in conjunction with an HTC Vive Pro VR headset and a haptic controller. It is used for training the tooth preparation procedures. Mainly the system uses 3D medical images. The images such as oral scan, computer tomography(CT) are transfered to 3D images. Also maxillofacial and standard oral 3D models are implemented within the system.

Overall, haptic-based simulators will provide an experience much similar to real-world scenarios with fewer resources. They have enabled users to experience the sense of touch and collaborate with sight to interact with virtual environments. Here the users can feel, palpate, and experience feedback forces in virtual environments. In addition, the system also does not need the close supervision of an instructor. But student progress can be properly monitored. So haptic-based simulators will be a good solution for dental institutions. Anyway new challenges can be identified with the haptic based simulations in the areas of validation of its evaluation system, the predictive validity of the simulator and a comparison with other VR training.

Behalf of haptic simulator systems, implementations have also focused on web based approaches with VP systems covering the main criterias of virtual simulation for skill training.

3.3 Web-SP

Web-based Simulation of Patients (Web-SP) can be identified as a general VP simulation system developed at Karolinska Institutet, Sweden [1]. There are twenty-four VPs created using the Web-SP built-in web-based authoring environment.

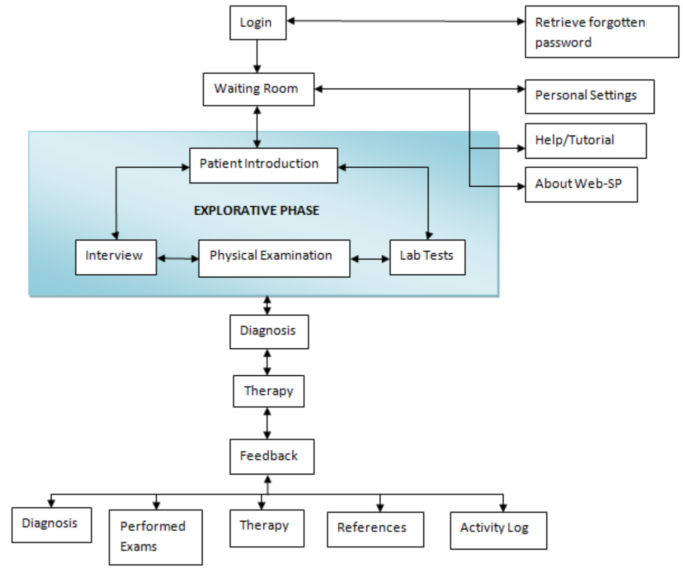

Fig. 1. The internal structure of Web-SP [21]

The system has been divided into several sections as patient introduction, patient interview, physical examination, labs/X-rays, diagnosis, therapy and feedback.

In Web-SP, navigating a patient case begins with logging in, as the figure 1 shows [21]. Then the user can select what case to use and after that the case is briefly presented by giving the patient introduction. After that the system lets users interview, examine and/or order tests on the patient. The system has an extensive database of history questions divided into main- and subcategories. In the patient interview section, users can ask any illness history question by selecting a question from that database. In order to prevent requesting the same information twice, answers to previously requested questions are stored in the ”asked questions area”. Answers are provided via photos with text or video sequences. In addition to these, there are several physical examination methods in the system. They are inspection, auscultation, palpation, percussion, etc. By selecting the appropriate body part, the user can choose an examination method. Text, image, sound, and/or video are all used to present the results. From an extensive set of lab tests, laboratory and imaging tests are ordered and to prevent having to constantly request a lab if results are forgotten, lab test results are kept in ”ordered labs”. Web-SP shows lab results as text, images and/or video.

Once a case has been thoroughly examined, the student is asked to enter a diagnosis, differentials, and motives based on the information gathered and the reflective exercises carried out [21]. Here a diagnosis must be entered before the therapy screen is accessible. Before accessing the feedback, a therapeutic proposal is necessary. With this the student has the opportunity to compare his or her responses with the instructor's and case creator's opinions on diagnosis and treatment in the feedback section. Each student receives personalised feedback on the patient interview, physical exam, and lab tests. However the Web-SP system compares the student's activities to the authors' recommendations in the case. Additionally, a chronological activity log of all actions made while resolving the patient cases is offered for on-screen review or in a printable format.

3.4 The Virtual world (VW)

Virtual world is a system [11] which mainly has addressed two research questions. One is whether the 3D environment provides greater interaction to the student than image and test-based PBL patient cases while the other one is whether the same virtual patient case handling is done by several groups individually and simultaneously.

Warburton [22] has suggested that the virtual world can provide a more realistic educational experience because of the improved 3D environment. For the implementation, Second Life (SL) by Linden Labs platform has been used. It has a suitable environment to model the pedagogical approaches while covering the D-PBL [23] case. In addition, there are easy-to-use construction tools in the construction. For editing, the scripting language can be used while the low cost and accessibility via laptops and desktops with no additional device, made developers attracted to the platform. Moreover, SL offers text-chat and voice communication tools has made the system more attractive.

However, we think that when developing a full 3D environment, SL can be identified as a good choice as in the virtual world all PBL groups are created as avatars. All the concurrent group practicals are handled by the ”holodeck” tool. Here the specialty is that all rooms are well isolated and students cannot communicate through it. Also, the virtual world has its own ability to change the background according to the group. In the examination process, students can click on that area and descriptions or 3D images will be triggered based on it. It is the same for the instrument selection too. When the student chooses an instrument from the inventory, a drop-down list will pop up based on their usage. Even without a full 3D environment, these features can be implemented. Additionally, if the information such as history records, figures, tables etc. can be stored in the initial setup or prior to the session, it has the ability to display those results too easily. Therefore, both of these techniques can be identified as major important aspects of an examination and investigation system of a patient.

3.5 COllaborative MEdical Tutor (COMET)

COMET [9], [10] is a combination of Intelligent Tutoring System (ITS) and computer-supported collaborative learning (CSCL). It is specifically developed for medical PBL where the system is designed for students to participate in skill training sessions remotely. COMET tries to make the students’ experience similar to human-tutored medical PBL sessions. When looking into the software architecture of the system, it is implemented as a Java client/server application. So that the students can access it via the internet or from a local area network. In addition, they can work as a group or any number of students can join the same session. To support students in collaborative learning and to build an effective communication channel between students, the system also contains different components. The four primary components can be identified as the student multi-modal interface, medical concept repository, student clinical reasoning model and tutoring module.

The multi-modal interface is the display that students use for learning. It includes three components a hypothesis board, chat pane and image pane. The hypothesis board is a shared workspace that students use to draw hypothesis nodes and link nodes based on their knowledge so that everyone can participate in it. Also, it helps to record the student activities and group ideas. According to the current focus of the group, the image is displayed in the image pane so that if one person sketches the image or points out things, everyone can see that. Other than that, if a student marks an area, which is defined as a valid hypothesis, it will automatically get it to the hypothesis board. To chat among the group members, the chat pane is used. With all the above features, it makes an attractive and efficient user interface for the system.

However, a proper method is needed for the system for receiving the observations in order to evaluate students’ knowledge and to provide tutoring hints. For this, COMET uses a Bayesian network. It contains two types of information. (1) hypothesis structure according to the scenario (2) application of medical concepts. Each hypothesis node has two states. One is that students know that is a valid hypothesis and other one is that the student does not know it is valid. To apply the medical concepts, nodes are divided into goals, general medical knowledge, and applied actions. This can be considered as an important feature in an evaluation system so that having such simple states from the basic level will help to identify the knowledge and the capacity of a student at each step instead of having feedback at the end.

The tutoring module in the COMET also plays a major role in the system as it is one of the highlighted features in the system. Here the system tries to give the experience of a real tutor. The paper [10] describes eight hint strategies used by human tutors. They are 1) focus group discussion using general hints, 2) focus group discussion using specific hints, 3) promote open discussion, 4) deflect uneducated guessing, 5) avoid jumping critical steps, 6) address incomplete information, 7) refer to experts in the group, and 8) promote collaborative discussion. COMET tries to develop all these qualities in its system using algorithms.

Overall, COMET is a collaborative learning environment. It provides a great platform for medical students to share their knowledge among themselves and actively participate in clinical sessions through its different components. The idea of bayesian networks to capture the students’ inputs is an efficient method to follow since it makes the evaluation process also easy.

3.6 The Virtual Patient Collection (VPC)

A Virtual Patient Collection [24] can also be identified as another approach that uses a collection of 66 VP s instead of a single one. So the system tries to give experience to a variety of patients considering factors including age, gender, occupation, etc. Here the coding framework has been divided into four main categories as patient data, patient representation, diagnoses, and setting. After analyzing the VPs the results were compared with data from the existing healthcare system. This was support to match curricular objectives of common symptoms, train clinical reasoning skills, and to complement the face-to-face courses.

3.7 Virtual Learning Environment (VLE)

The VLE [25] is specially designed for diagnosis and treatment planning in dentistry. It is a web-based database application. The application is divided into five different sections. They are history taking, clinical examination, X-rays(Radiographs), diagnosis and feedback on the usage.

In history taking, initially, the system gives a brief introduction in one sentence. The student can ask questions freely. Then in the clinical examination part students can ask for clinical images such as intraoral clinical images or a clinical examination such as bleeding on probing. The system provides figures, tables, and multimedia information like sounds, and video clips. Also, the system provides X-rays(Radiographs). The highlighted characteristic is the system provides a full-mouth radiographic chart including both bitewings and periapical X-rays. It lets students select and enlarge the space. After that, diagnosis, treatment planning, and prognosis can be done by the student as a free text. Finally, evaluation is done and the system gives feedback to the student. Moreover, student activities within the session are recorded.

The idea of addressing the sections separately is good. It can be further improved by facilitating a selection of the parameters to be investigated during the clinical examination and by providing high-quality images of instruments that need for the investigation. If so, that students can get ideas for practical scenarios and suitable tool selection (3D graphics). Also without giving the exact figure, allowing students to choose the area that needs to be examined is better. When giving X-ray images, the system follows that technique. But in real scenarios, without exact need, it is not wise to expose a patient to full mouth radiographs. Furthermore, sending the reports of the activities to the teacher is also a good thing. To improve that, we can add a feature to request comments from outsiders. That feedback can be added to the system feedback. Another important feature is measuring the time taken for the session. It shows the students' confidence and fluency in their knowledge.

3.8 Virtual Patient via an Artificial Intelligence Chatbot

This is an approach which has used integrated VPs with AI. A VP, named 'Julia' has been implemented with a conversational chatbot with AI [26]. Five different categories have been identified to answer questions by the VP as Anamnes, Description of the pain, Relationship of the pain with stimuli, Previous dental treatments and Intraoral exploration. The system has the ability to identify different ways of asking the same question using natural language processing algorithms. Also, formal language has been used so that it has the ability to answer some questions that were even unrelated to the clinical case. In order for Julia to generate curiosity among the students and given the possibility that some questions were not focused on the clinical case, In addition, it also has the capability to understand the nuances of human language by learning through action and feedback.

At the beginning of the interaction with Julia, she introduces herself and the directions for the student will be given about the process. Julia is able to answer different questions about the current condition. Colloquial responses to intimate questions that were unrelated to the case were established in order to arouse students' curiosity and redirect them. In case of reaching an incorrect diagnosis, Julia redirects the student.

3.9 ALICE(Artificial Interface for Clinical Education)

A Web-based IPS called ALICE [27] enables students to move around a virtual environment in first-person view, much as in a video game. Also, ALICE is cost-free, accessible to all interested teachers, and has a high rate of student acceptance. For the uniqueness of the system, a teaching module that replicates patients with complex oncological diseases was built. This provides the chance for students to use their newly acquired knowledge on virtual patients as well as to acquire knowledge.

4 Specific features

When considering the existing implementations, a number of specific features can be identified to support effective virtual realism. Table 1 shows a clear comparison of the above identified features in every implementation discussed above. This includes the introduction to the system, Examination and Investigation, Chat system, scenario selection process and feedback system.

4.1 Introduction to the system

The feature of providing an introduction to the system can be identified in VW and ALICE implementations.

In VW before the session goes on "live", one member from each team will be given an introductory video clip to verify they understood the process. Although this process verifies that one member from each team gets an idea of how the simulator works, giving that knowledge to all team members will be an efficient way so that initially everyone is at the same level of knowledge.

In ALICE [27], a brief tutorial case that explains the fundamental controls and features is provided at the beginning. The idea of giving a brief tutorial case helps to reduce the time spent by students to complete one case and to minimize their mistakes while working on the case.

4.2 Examination and Investigation

For a training simulator, it is important to gather information through the history of the presenting complaint, medical history, habits, previous dental treatments and social history by asking the relevant questions from the patient to do further examination and investigation. This feature can be seen in VRTS and COMET as shown in table 1.

VRTS is an implementation that describes a way of asking questions covering all the relevant areas. Here the questionnaires are divided into four sections: content, anatomy, applicability, and usability. This ensures the completeness of the content of the training simulation. In detail, the section on anatomy evaluates the accuracy of the anatomical structure of the oral cavity, the external shape and the internal shape. In the applicability category, it evaluates

the applicability of the simulator to practical education. Finally, the usability item, it compares the effectiveness of doing practical in a VR simulator vs a practical scenario.

TABLE 1
Table 1.0 Analysis : Functional comparison

Features	Techniques	Web-SP	COMET	VW	VPC	VRTS	VLE	ALICE	AI chat-bot
Haptic-based						yes			
Introduction to the system	Instruction in text					yes			yes
	Instruction in video			yes				yes	
History taking	Textual	yes		yes	yes	yes	yes	yes	yes
Examination and investigation	Textual		yes	yes	yes		yes	yes	yes
	Selecting from drop-down list	yes							
	Providing resources with 3D images			yes		yes			
	Providing resources with 2D images	yes	yes				yes	yes	
	Proving resources with videos							yes	
PBL			yes	yes					
Chat System (with the patient)	Textual			yes			yes		yes
Tool Selection	3D images			yes		yes			
Diagnosis	Only diagnosis		yes	yes					
	Diagnosis with treatment instructions	yes				yes	yes	yes	
Feedback System	Textual	yes	yes	yes		yes	yes		yes
	Access to the previous diagnosis	yes							
	Case feedback for the tutor						yes		
Individual Supervision	Tracking log	yes					yes		
	Evaluation					yes	yes	yes	yes

In addition to that, the system also considers the students' preferences. However, with these features, improvements could be made to a newly developing training simulator. When defining a questionnaire, a score can be defined for each question asked by the student considering the above facts and also graphical representations can be used to display the score of the students' performances with selected parameters such as content, anatomy, etc.

COMET also has a specific way to take input from the student. It contains a hierarchical medical concept repository. Here the students can view the figure of the body shown by the system. Each body part includes a specific index which is a numeric scale where related body parts are indexed closely. Students have the ability to search deeply to get relevant body parts. As an example, 20000 represents the Musculoskeletal system, 21000 represents the Bones of the Cranium and face, and 21110 represents the Frontal bone. All the valid hypotheses are stored in the repository and students can get them from the index. Thus it makes the functions easy for the system as if not the students may have many definitions for the same medical concept. If the students are allowed for direct text inputs without any support or guidance from the system, the students may not receive the needed support from the system since the system is implemented to respond according to keywords. But if inputs are predefined and students have the ability to choose the options, it is more beneficial for the student as well as the system in guiding and evaluation processes.

4.3 Chat system

A text-based chat interface is a great communication tool in SL where the users can easily interact with the system. In the virtual world, it is used by learners to interact with the VP. There the system provides the responses based on the keywords in it. Here the expected responses were initially gathered from traditional paper cases. According to [11] , chatting with VP is easy to handle since the keywords can be guessed. But it is difficult when coming to group discussions. Therefore when focusing on the individual skill training sessions, the chat option with the VP will be a better initial step than having group discussions. Moreover, according to the research on the virtual world, suggesting alternative ways and questions by the system also make the process complicated since patient responses include verbal and non-verbal communication. But if only text-based communication is used and every question has already defined answers, we can try on adding suggestions including alternative ways.

But in COMET, there is no sense of chat between the student and the VP because it gives only a detailed scenario. Students then draw hypothesis diagrams and diagnose the disease. However, it has a chat feature among the group members which makes it efficient when working as a group. But if implementing a system to train an individual student is considered, having a chat between the student and the VP will make the system more effective and efficient.

A more advanced communication system is in the VLE. It is Free Text-based communication. There are no predefined options or pathways. The system responds according to the keywords/trigger words by searching in the database. This will make the VP much similar to the ideal situation which is in the real world. But the design task will be more complicated since the system must have a good database of keywords as well as it must have the ability to identify nonrelated questions asked by the student to make the system complete and user friendly. Here, the system should identify the way students ask questions. Some possible incidents are, that the questions are correct but the information is missing from the database, questions are incorrect, questions are correct but out of the answering pattern of the system, responses are not of expected quality instead follow keywords and no relationship between the responses. So those incidents must be considered at the implementation level.

4.4 Selecting scenarios

In the virtual world, for the experiments, they first chose a single PBL case covering a very specific area. It only covered the gastrointestinal system, liver and kidneys. For selecting a scenario they have considered two main factors. They are (i) it must include exploring several areas so that the system can give more help in 3D views (ii) It must have high interaction with tools such as stethoscopes, ultrasound machines, and computer health records. Behalf of the virtual world, COMET itself considers the hypothesis structure rather than a specific disease. Surveys were done to create the initial Biesian network. For that, data collected from medical PBL tutorials where that data contains tape recordings of tutorial sessions related to the selected disease.

However, the selection of the scenarios can also be applied to a specific area such as oral cavity-related diseases. when considering the skill training for dentistry, in most cases the examination location will be the oral cavity and surroundings. But when considering the interaction with tools, much attention can be given to that as there are different tools used when checking a patient. Here selecting parameters for observation by students is also a necessary factor to be considered. The example scenarios which need a selection of parameters are observing the patient/relevant area in the mouth, checking the area/tooth with a tool (an instrument) and touching the area (palpation) or tapping a tooth (percussion). Apart from the tools, the amount of examination methods related to the scenario is also an important matter to consider. Because it will help to check the student's knowledge in that area too. Here tests such as X-ray, sensibility recording, blood test, etc can be considered.

4.5 Evaluation and Feedback criteria

As this is a learning system, student performance evaluation and giving feedback is an essential aspect. It is necessary to generate final scores and give instructions about the student's failure points such as missed parameters, wrong choices, etc.

In this case, COMET [9], [10] uses conditional probability tables where the probabilities depend on the fact that whether the student is able to apply the appropriate piece of knowledge in each step. Each hypothesis node has a conditional probability table based on the condition of whether the student has correctly identified the cause-effect relationship by using their knowledge. For some nodes, they have used simple AND gates as conditional probability tables. The system should determine a causal path that can be taken by each student. There, the path which has the highest probability is used. Some of the probabilities in that path are calculated. Also, it is necessary to identify the causal paths that direct to group discussions since when a discussion goes the wrong direction tutoring module in the system should generate hints to help them. Calculating the sums of each student taken path will be beneficial at that time. Because if the total sums are reduced, the system can identify that most of the students are out of focus. Then it will do further examinations to make sure at least one student is in the focused area. So, by using this kind of technique, the system cleverly handles the student evaluation and gives feedback.

In Web-SP two types of feedback are available to students as constructive and neutral. While constructive feedback [1] is an automatically generated checklist that matches and compares student recommendations to expert recommendations, Neutral feedback is an automatically generated display of expert opinion and recommendations but does not provide any comparison between students and experts. The student has the opportunity to compare his or her responses with the instructor's and case creator's opinions on diagnosis and treatment in the feedback section. Each student receives personalized feedback on the patient interview, physical exam, and lab tests [21]. The Web-SP system compares the student's activities to the authors' recommendations in the case. There is no individualized feedback on the diagnosis or therapy. The student must contrast his or her responses in those areas with what the case author has suggested as the suggested correct response. For an on-screen review or in a printable version for additional discussion, a chronological activity log of all actions made while resolving the patient cases is also offered.

In VLE, it allows giving diagnoses as free text and the answers will be evaluated and feedback will be given. The highlighted feature is other than the evaluation part it saves all session activities as a log. The activities include time, questions asked, images requested and the behavior between the sections. It is sent by e-mail to the teacher responsible for the case automatically. So, if free-text answers are out of the scope of the system's database, teachers can evaluate them.

In the implementation, Web-SP maintains a tracking log over the students' activities. As a result those activities can be investigated including the logged time, the accessed VP, duration, all detailed actions that were performed and even their order [21]. This can be considered as an important aspect for a virtual student evaluation system so that the above information can provide the tutor a better understanding regarding the students' engagement with the system. As a result, the tutor can get feedback about each case even as a percentage of frequency of usage and do the necessary improvements based on the receiving data. Thus an efficient and effective system can be implemented covering all the aspects from both the tutor's and student's side.

Similarly, as Web-SP keeps a log or history of student previous activities, the students' proposed diagnosis and therapy were stored in the feedback area [21]. This can also be identified as an important approach for an developing tutoring system, allowing students to go through previous cases, assignments, their answers and received feedbacks.

5 Game Engines

As mentioned earlier, the images, figures, and tools mentioned in the scenarios in virtual simulations need graphical outputs. They should be capable of displaying 3-dimensional models with a high level of realism and user interfaces for operating and configuration of the simulator and an underlying physical simulation model. However, virtual simulation tools in medical education are not available everywhere due to the rising complexity. Commercial training tools, sadly, are very expensive and have a very thin user base. As an example, MedSim-Eagle [28] is a full-scale mannequin simulator that considers the student clinical practice in a virtual environment but due to the cost-intensiveness, it is likely to be unaffordable for most institutions. The virtual world [11] which is another high-level clinical simulation design, has also been implemented with virtual world Second Life (SL) by Linden Labs platform which is not freely available. In addition to that, ethical issues [29] have also been identified in the final implementation. Therefore, as a solution for this, game engines have become one major approach in implementing virtual realism for medical simulations with the wanted features and reducing the above issues.

A game engine is a complex software system necessary for developing and playing games and it builds a bridge between game content and the underlying hardware. With the help of an operating system abstraction layer, the same game content can be run on many platforms using game engines. They [30], [31] provide special benefits for the development of highly interactive and cooperative settings. Anyway, the use of games or game engines for medical education is a little-explored research subject with many aspects still to be investigated.

Modern game engines consist of several functional blocks including a Graphics engine, AI engine, Physics engine, Audio engine, etc. All the data related to graphical content and visual effects are loaded, displayed, managed, and altered by the graphics engine. It is possible to load, texture, light, and animate 3D models of players, objects, landscapes, buildings, animals, and other elements. As a result, this can be used for implementing virtual environments by developing relevant 3D graphics. Once the platform is familiar to the developer, the task will be easier than developing from scratch using other web-based technologies such as HTML, Java, JavaScript, etc. The reason is the hardware layer-related functionalities and other basic image rendering functions are already defined in game engines. Virtual simulation systems like COMET, VLE and Web-SP have already used these web-based technologies for their implementations.

With the presence of many game engines, the selection of the most suitable one for implementation should be done after an evaluation. Researches have been conducted to evaluate the game engines for their suitability for collaborative simulated surgical training applications. For this, factors including stability, availability, the possibility of custom content creation, and the interaction of multiple users via a network have been considered. Also, higher attention has been paid to the fact that compatibility to create custom medical models as some of the game engines are not suitable in that case. However, many features found in contemporary game engines have been identified as useful to create applications for clinical training.The highly developed capabilities of graphics, audio and networks enable application developers to concentrate on content rather than implementation specifics. As a final criteria of the selection, important aspects for reduction of the complexity of the editing process has been considered as there is no need for purchasing, installing and setting up external editors and necessary conversion tools.

For the comparisons four highest-ranked game engines are chosen. They are Unreal engine 2, idTech 4, Source engine and Unity engine. The comparison has been done considering the aspects including editing, content creation and gameplay.

When considered, the Unreal Engine 2 has a model viewer, texture browser, script editor and other components necessary for editing a map. The file format for inserting custom models can be .LWO (Lightwave Object File), or .ASE (ASCII Scene Exporter). When considering the gameplay, the non-physical actions and states are well synchronized between the server and the client.

In idTech 4, editing can start separately for example, maps, articulated figures, effects, materials, and scripts. Also, a custom content skeleton model, imported from an .ASE file. At gameplay, player positions, orientations and states with optical effects are synchronised well between server and client.

On the other hand, the editor of the Source engine can be switched into different modes, such as constructing solid objects, placing complex objects, moving objects, and texturing them etc. Inserting content is different and a bit complex in the source engine. To convert every model to game engine format, 'compiling instruction' should be provided.

If it is a 3D model(.smd), it will convert to several single files. They are to hold information about geometry (.vvd), animations (.mdl) and physics (.phy). If there is additional data, .vmt file formats are used. It is necessary in specular lightning, normal mapping and physical properties. On the gameplay side, on both the server and the client, the physical simulation and the position,orientation and state of the user's character are in perfect synchronization.

When considering the three engines, a clear difference can be identified in unity3D [32]. It has an integrated development framework that creates rich solutions and out-of-box functionality to make games other than so-called functionalities. According to the live comparison between Unity and Unreal game engines [31], [33], using Unity3D can assemble assets and art into environments and scenes, add audio, special effects, lighting and animations. It is also considered as the most popular game engine among developers which has 45% share of the market and it affects over 600 million gamers around the globe. The general features highlighted in unity are mainly the 3D graphical support with the powerful graphical engine which is optimized for many devices (consistent FPS across hundreds of devices), compatible in 25 different platforms including: IOS, Android, Nintendo Switch, VR/AR etc., fair pricing and huge asset store with prebuilt templates that are plug and play. Most importantly Unity has a huge community of developers so that there are several online courses, and discussion forums available on the internet for the help of beginners. A cons paper identified that difficulty in optimizing graphically intensive games(needs custom models etc.) and integrating mobile APIs, advertising etc. are more challenging than other engines.

Apart from that if Unreal engine is used, key advantages will be profiler in default version, graphical capabilities are way out of the competition so that it has a good quality in images and better templates on its asset store. But when using Unreal engine, due to the use of C++, it requires more programming experience than C or JavaScript. In addition to that, limited third-party APIs compared to other engines and builds that are not optimized well for lower spec devices can be considered as disadvantages of Unreal engine.

With the comparisons, it can be identified that both Unity and unreal engines features can be used for clinical simulations. but comparing all these details, Unity3D contains the major number of suitable factors for implementing a virtual simulator for clinical-based practices. As a VR training simulator in tooth preparation practice[4] focuses on rendering 3D images, the unity3D game engine. Medical images such as computed tomography (CT), oral scan, and magnetic resonance imaging of patients were made into 3D imaged and a standard oral and maxillofacial 3D model was developed.

6 Discussion

When discussing the existing implementations, pros and cons can be identified for each approach separately. While some contain many features that would be necessary for building a clinical training application some features can be identified as having not met the relevant satisfactory levels.

Virtual world describes the things that worked well and didn't work well in the virtual world implementation. Issues have been identified in chatting with VP as the system has been implemented to reply according to the keywords (pattern-matched phrase or word). This can result in creating a poor structure or a wrong scenario in some cases. Therefore, in order to define an exact scenario, it would be better to have a list of questions for the history taking of the patient. So that the students can choose the options and get answers. If the answers are also predefined, it will create a better structure and thus resolve the issue of having a confusing sequence of facts for each case.

Also adding a completely 3D environment will cause some distractions. Students might find the system not as realistic but enjoyable. Even according to the feedback in the virtual world, it is better to focus on 3D figures only when necessary. As an example, if a student wants to examine the mouth of a person, it won't be necessary to create full 3D clinical rooms and avatars in dentistry. If the system can provide a good quality 3D image, it will be satisfactory for the student to examine by keeping the focus on the relevant area.

Also in COMET, although the system is very interactive and well-performed, it would be better if some more interaction with the virtual patient could be added. At least in history taking part, students should have the ability to chat with the patient as currently, the only data provided is the initial information given by the system. Anyway, the system was able to cover the above minor issues by providing an excellent tutoring module that is exactly similar to the human tutor. Evaluations also have proved that system feedback is very similar to the human tutor.

Therefore, when considering the above facts it can be identified that for a more improved implementation, a student assessment system with a detailed feedback is needed than just giving an evaluation for the student. Specially it would be better if an efficient feedback system with case by case feedback can be introduced. In addition, keeping the records for a better analysis of the performance of students can be identified as another feature to be improved. It would make the system more useful, if the records of history of students including tracking logs. activity logs and evaluations could be added to the system as a facility for an administrator of the relevant institute.

Further when it comes to the implementation technologies, most of the haptic-based simulations use game engines for connecting haptic devices. As an example, VRTS has used unity3D in their implementation. On the other hand there can be identified web based implementations like Web-SP and VLE as well. Although they can be used efficiently to be combined with other systems, less visual aids and implementing from the scratch will be challenging areas. But for this, game engines will be a good solution for a better visualization by creating 3D images since the platforms can be used for converting 2D images to 3D images and generating new 3D images by using scripts. It will provide a good sense of visual aids in practicing for the students.

7 Conclusion

It is clear that significant work has been done for the last few decades in the medical industry including dentistry with the involvement of virtual realism. Nevertheless, many implementations can be discovered which have focused on the implementation details rather than the content inside. Therefore the existent physical simulation capabilities of the implementations including game engines could be utilized to enhance the realism of these training scenarios connected to a patient. In addition, the variety of training scenarios that are based on real-life cases can be further improved using tools for automatically converting real patient data. ex: to game engine-specific files. Implementation of more case studies on education and training such as improving learning outcomes and measuring interactivity can also be further investigated.

Similarly, the tutoring processes could be improved without introducing them simply as an assessment or exam preparation tool. Creative ways for students to use the system in the given approach for their own learning needs and purposes should be identified so that to provide maximum assistance for their skill training. Even from the feedback more interactive solutions can be proposed to develop and enhance students' decision-making abilities. These improvements would facilitate the development of different scenarios and will allow even more realistic simulations.

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