Evaluation of MUVES: Needs and Results

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Abstract: *The use of virtual patients in medical education is increasing rapidly. The integration of the e-learning modules is essential for their success. Quality Assurance measures have been applied to MUVES; it has been assessed using some different testing types. Also a collection of virtual patients of MUVES were introduced and introduction sessions were organized, and then divided students into small groups. Two studies were done using questionnaires and log file analysis, both studies measured student's satisfaction, learning outcome, design of virtual patients and the perception of different integration scenarios.*
Results:
Key words: *Virtual Environment, Virtual Patient, Case Based Learning, Medical E-Learning.*

4. Introduction

The medical colleges in Mansoura and Monofeya Universities have a main focus of interest in introduction of new teaching methodologies. One of these new teaching methodologies is Virtual Patients (VPs). VPs are interactive computer systems that simulate real life clinical scenarios [1]. VPs allow students to get standardized experiences and knowledge with clinical problems. Students can be introduced to uncommon diseases regardless of real patient availability. Virtual patient systems are interactive learning environments in which students can learn relevant skills without risk for real patients, like clinical decision making. Training can be repeated with these systems as needed and feedback should be provided to improve skills of students.

Evaluation in e-learning systems used to gather information about the impact or effectiveness of this Web-based learning event [2]. Measurements might be used to improve the offering, determine if the system objectives were achieved, or determine if the offering has been of value to the organization [3].

This paper presents the evaluation results of MUVES, a virtual environment for medical e-learning in medicine college of Mansoura. MUVES is a using the problem based approach, in which students are choosing what is the next step in the process of clinical case diagnosis. They have to gather information from history questions, physical examination, laboratory and technical tests, and then they should be able to make appropriate decision accordingly. MUVES provides a user-friendly interface and necessary tools to generate virtual patients and play virtual patients.

Section 2 of this paper gives a short overview about MUVES and its functionality, then the rest of paper describes the evaluation result of MUVES. Section 3 describes MUVES quality

evaluation for functional system testing results and some nonfunctional measures like performance. Section 3 presents teachers evaluation and then section 4 presents students evaluation, which are both based on a survey conducted in the two medical colleges. Respondents of this survey have given feedback on the current and future use of MUVES, including different educational settings and scenarios within which virtual patient have been used. Finally section 5 presents the usability analysis of the system based on system logs analysis, which presented many important indicators of medical elearning systems design and implementation.

5.   Overview of MUVES

MUVES is a medical e-learning system for authoring and delivering CBL to medicine students based on MVP standards [4]. MUVES can work as helper tool for medicine teachers to demonstrate the diagnosis process for students over the web in a virtual lecture style. Teachers can select or create a new VP template, these templates are categorized by teacher upon their relevance to subjects. Each VP template contains a complete VP data and media resources, the teacher can create an instance from this template to start performing the diagnosis process on this instance. The idea of creating templates is to "reuse" previously created VPs and make it easier for creating VPs rather than copying files. After creating the instance the teacher may need to change some VP data for more clarification on this case or to add new important information needed for diagnosis like up-normal values for some lab elements, or increase the measure of blood pressure, etc. An example of the authoring module is shown in figure 1.
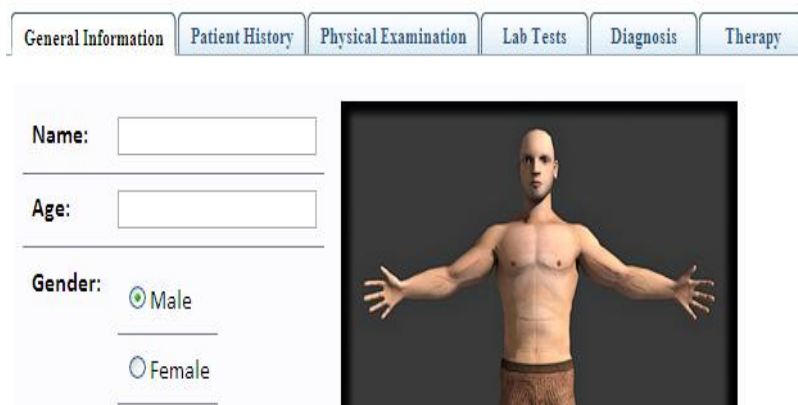

Figure 1 VP authoring Module

All the previous steps are performed "offline" or away of students. Once the teacher finishes his updates on the instance chosen, he can start the virtual lecture. The virtual lecture items are broadcasted to students over the web, starting with VP data and media resources. Teacher starts his lecture using collaboration tools like audio/video streaming, whiteboard, and performing

visible physical examination on the VP instance. The physical examination is performed using a rich set of physician tools, and possibly to acquire some lab results for this VP instance. Each step of the diagnosis process can be opened for discussion by students using a simple chatting tool with the teacher until the teacher reach the conclusion of the diagnosis student can submit their questions and discuss the reasonability of diagnosis. The lecture can be saved to the Virtual Lecturers Library (VLL) and can be reviewed by student later. Another important feature of MUVES is it can be used as an assessment tool for students. Teacher can "setup" the instance as introduced previously, but he will assign the diagnosis process to a group of students who need to collaborate together to conclude the possible diagnosis with guidance of the teacher.

6.   MUVES Quality Evaluation

MUVES has been applied to a full test cycle before publishing. The testing aimed to enhance the quality of the system by insuring that all functional and nonfunctional requirements have been met. Figure 2 shows the progress of closing defects found in system testing along different versions of the system
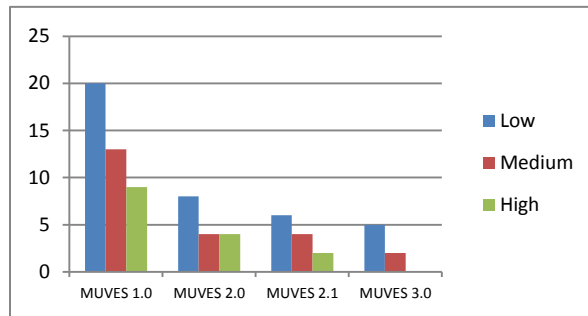

Figure 2. MUVES Versions Bugs Report

Good progress has been achieved in decreasing the number of bugs, especially ones of high severity which represents bugs of type unplanned error screen or fatal errors. MUVES 3.0 which is the current version still has some minor errors like some JavaScript errors which are caused by using development tools like JQuery and AJAX. The continuous bug findings are caused by the continuous additions and enhancements to the system.

Another type of testing was performed to assess some functional requirements like performance testing. The primary goal of performance testing is to study application performance under normal load and heavy load for sustained durations or for short durations. The reports and graphs generated at the end of the test session should provide important indicators for application stability under heavy load, and response time of the system is reasonable.

An important part of a load test process is to analyze the errors and adjust the tests in order to achieve meaningful and accurate results from the test. The following reports and graphs give detailed indicators for system performance.

Time-based frequency of errors over the duration of the test. Error rate shown in figure 2 is an important metric in stress testing. This indicates the maximum number of users that can be served correctly, without errors and hence your site capacity. You will also need to watch error rate during the test to verify that the error is within acceptable range even after a long run.
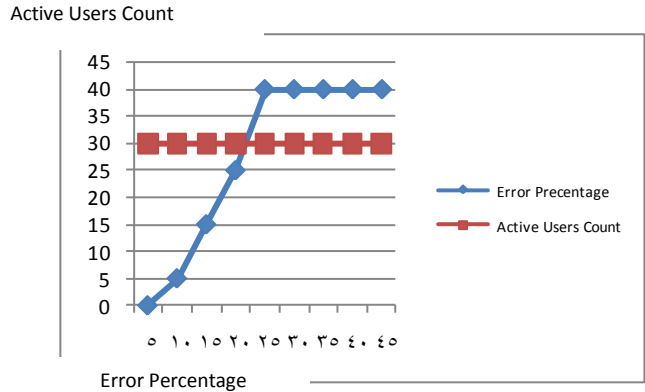
Active Users Count

Error Percentage

Figure 3. Error Rate Graph: Time Vs Error

Graph shown in figure 4 indicates average response time for the each page through time. Each bar in the graph is the average server response time for each page. From this graph it possible to identify peaks in the response time for critical pages. Ideal behavior of response time graph is that response time does not increase with load. The point at which the graph increases sharply indicates beyond this load server cannot serve the request and users will see no response or a very slow response.
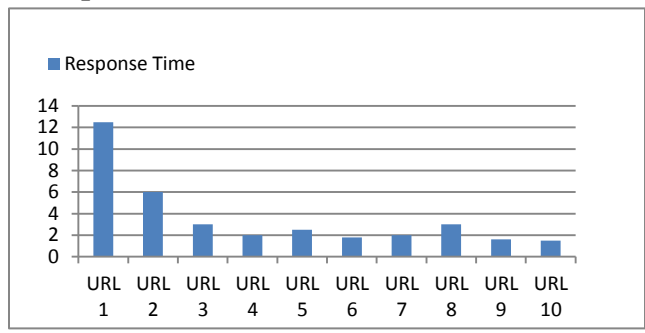

Figure 4. Response Time Graph

7.   Teachers' evaluation

This evaluation was conducted by interview with a group of teachers to capture their detailed feedback on the process of creating VPs and integration with standard systems in a qualitative manner. Teachers commented that their creating was done in two steps.

Firstly, teachers would create the existing cases from international references, there is a range of differing healthcare cultures from most rural to most urban). In addition to this the teacher would also check the validity of units, reference ranges for laboratory tests, and healthcare NHS protocols like the National Institute of Clinical Excellence guidelines. This was a straight forward process and took approximately an hour per case as there weren't many changes in how a patient is treated and cared for between local and foreign.

Secondly, the VPs needed to be story-boarded and expanded. This was done during an initial brainstorm meeting between two subject matter experts.
A few questions have been asked to teachers to evaluate the idea and the system.

2.1   In general, is there a place for VPs in the curriculum? Please explain your answer.

Every form of teaching targets a specific area. The traditional fact-based approaches don't allow the students to learn in a realistic environment, to make mistakes and by doing so to became more skilled in the clinical decision making process. The contact with the real patients on the wards is very limited and the prevalence of some important diseases is too small to give the opportunity for each student to come face to face with it and learn how to proceed and how to make the right decisions. That's why there is a gap for realistic and interactive virtual patients in the curricula which are always accessible to the students. Many people learn by doing, for some it's also much more easier to learn in this way. Students can't learn how to make decision with other resources. Students have to be able to make mistakes.

2.2 How do VPs compare with other types of resources that teachers create for the student? Do they differ in quality from other types of learning resources used by teachers?
The VPs and their quality is so different that they're not really comparable to other learning resources. They're targeting other parts of curriculum. To speak about the quality of a VP, we need to define how this quality should be estimated.

2.3 On average, how long did it take you to create a case?
First stage (brainstorming): about 1hr, Second stage: writing the content and creating the pathways was very time consuming, Total time needed: 9 hours.

2.4 What experience is needed in order to create VPs effectively?

Native language speaker and experienced professional clinician. It helps to have been in the situation to make the VP realistic (To be able to find enough alternative paths)

**2.5 What do you think are the best features of?**

You really feel like you're in the case – but more in a tutorial way.

8.   Students survey results

A group of students from medical faculties were selected to be trained on using MUVES. After conducting training sessions, students worked with three medical cases. Virtual patients were developed by teachers, required support was provided to help them on the authoring tools. All students were divided into small groups, each group was using one computer. Sessions durations were about 2 hours, and were led by teachers and research team. After working through the VPs, students were asked to fill in questionnaire comparing virtual patients as a new method of teaching with the classic methods of teaching. The classic methods consisted of bed side teaching and theoretical lectures.

This is a questionnaire completed by 12 students who completed individual questionnaires following the virtual patients that were delivered weekly in their module. Below are the results:
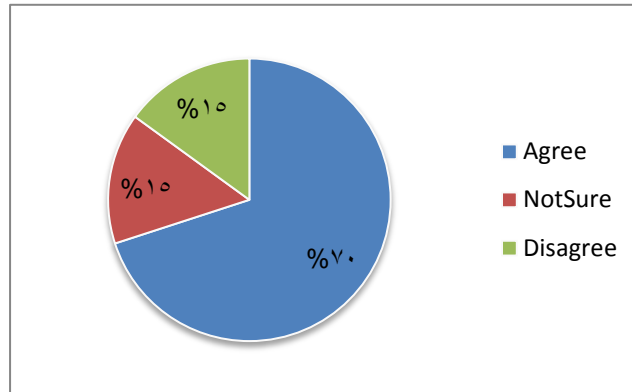
A- After completing this case, I feel better prepared to confirm a diagnosis and exclude diagnosis in a real life patient with this complaint.
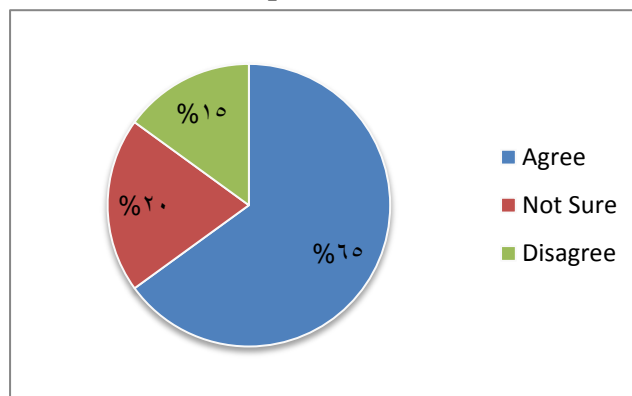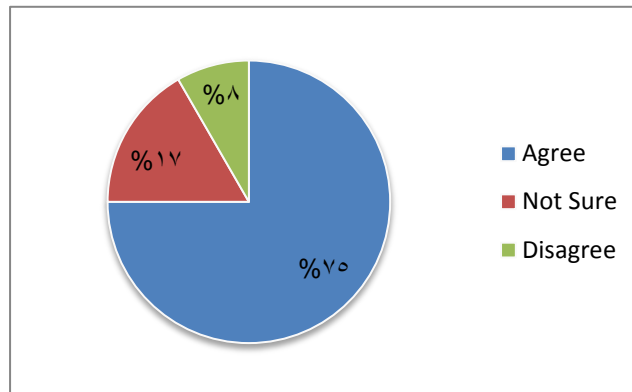

B- The feedback I received was helpful in enhancing my diagnostic reasoning in this case
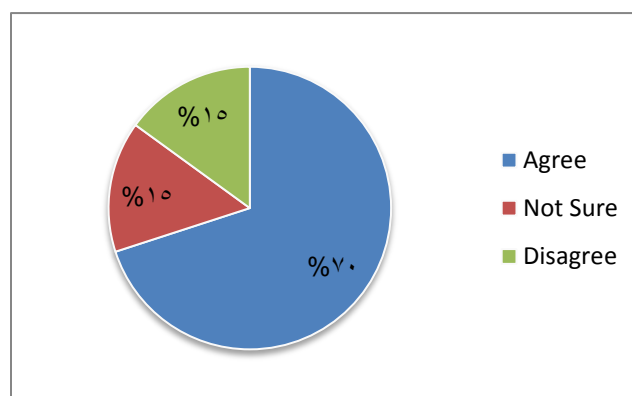
C-After completing this case I feel better prepared to care for a real life patient with this complaint.


D- The questions I was asked while working through this case were helpful in enhancing my diagnostic reasoning in this case.

E-While working through this case, I was actively engaged in revising my initial image of the patient's problem as new information became available.
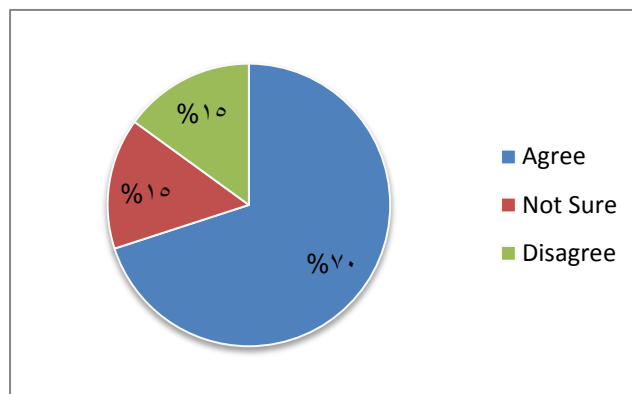
F-While working on this case, I felt I had to make the same decisions a doctor would make in real life.
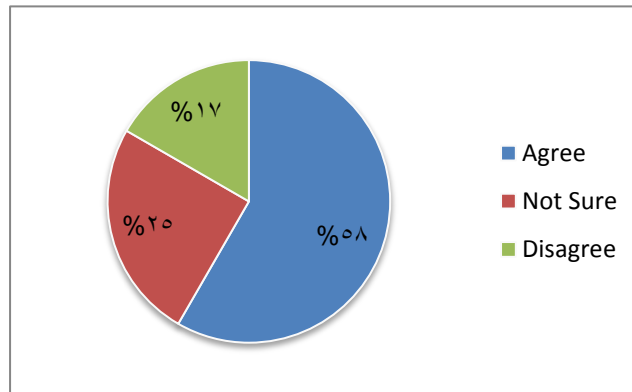
G-While working through this case, I was actively engaged in creating a short summary of the patient's problem using medical terms.
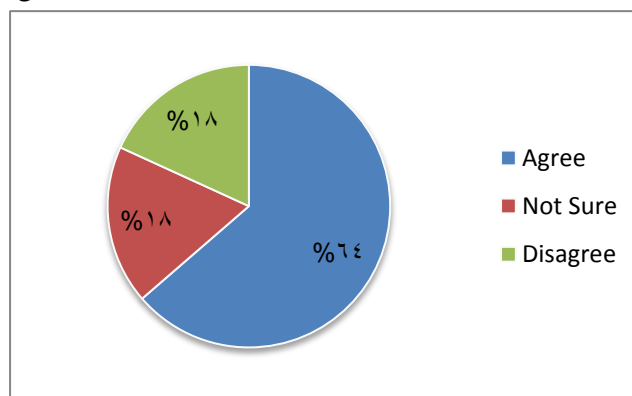
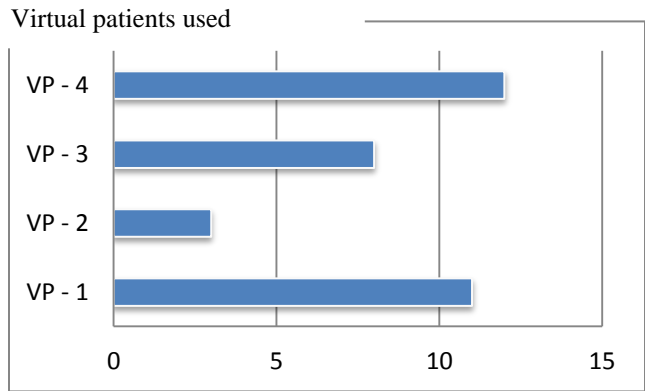H-While working through this case, I was actively engaged in thinking about which findings supported or refuted each diagnosis in my differential diagnosis.
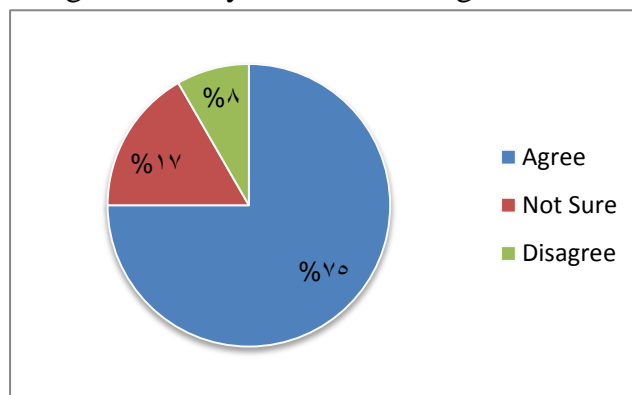
I-Overall, working through this case was a worthwhile learning experience.

Virtual patients used

VP - 4

VP - 3

VP - 2

VP - 1

0   5   10   15

9.   Usability Analysis

During the whole time all activities of the participants in MUVES were recorded in the form of a Log file. The participants produced between 11273 and 26158 lines in the log file. The navigational behavior of each participant was analyzed. MUVES has five main navigation forms: a tree structure (similar to the Windows Explorer), breadcrumbs (a description of the hierarchical path on top of the main text field), a sitemap and links within the text. In addition to the main forms of navigation, additional factors have been taken into consideration: number of clicks on links leading to a virtual lecture, number of clicks on virtual exams. The last two categories might also be seen as text links but we think their function differs considerably from normal text links, therefore they have been analyzed separately. Table 1 contains a minimum and a maximum number for all categories. These numbers show the maximum (minimum) number of clicks in this category for a specific user, the average number of clicks in this category and the percentage across all users. The values in the min- and max-lines do not necessarily come from one single user.

These data also show that the tree navigation was most popular among users. It is probably so attractive because all users are well acquainted with this form of navigation and it can be used easily because it is always visible on the screen (in contrast to the sitemap which has to be accessed specifically). The other methods of navigation were only used rarely.

Table 1: Usage of Various Navigational Practices. Navigation Bar (NAV), Tree (TR), Breadcrumbs (BC), Link within Text (TXT), Sitemap (SM), Virtual Lecture (VL), Virtual Exam (VE).

	NAV	TR	BC	TXT	SM	VL	VE
Min.	84	437	0	72	1	63	12
Max.	289	2262	482	883	479	191	112
Avg.	186.5	1349.5	241	477.5	240	127	62
Result	7%	50%	9%	18%	9%	5%	2%

The average number of clicks for breadcrumbs (241.0) is due to one single user who used this form of navigation 482 times. The other users only adopted this form of navigation between 0 and 11 times. The same user also used the sitemap comparatively often. He c licked 479 times on the sitemap to access single pages.

10.   Results

Surveys' results have been summarized into the following subjects so that they can inform current and future developments based on student feedback:

11.   Motivation

The feedback from the teachers and students suggests that they found the use of virtual patients (VPs) highly motivating. They found the interactive nature of the VPs particularly motivating. This was highlighted by the following quotes from one of the students when comparing the use of VPs with traditional textbook learning:

"It just makes learning a bit more interesting, rather than just learning from a textbook. Because it's always more helpful going in and seeing patients and seeing cases, and this is a way to do that when there isn't a patient, or when it's in the evening and you just want to sit in bed with your Laptop. I have to say I've got books at home but because it doesn't take you through step by step, it just asks you general questions, I find it a lot duller than this. I'd rather use this."

Another general consensus from the focus group was that the students felt that VPs were quick and convenient to use and learn from. They added that it was something that they were easily able to integrate into their studying routine at home. This in turn increased their motivation for using VPs. This was highlighted by the following quote from one of the students:

"I think whenever I want to do some revision or study it always seems like a big thing, I need to set aside at least an hour, whereas with this, I just did it. I had ten minutes and I was a bit bored. I was online, I wanted to go on Facebook, and then there was nothing left to do on

Facebook; I had gone through all my friends. I don't know what else to do. And so I clicked on the VP and I went through it. So it's just being able to slot it in whenever you want. Because I spend a lot of time on the Internet and so it was something I could do when I was bored."

The students also found the use of pictures within the VPs very motivating because it made the learning experience more personal. Especially when treating VPs that they were able to put a face to the name. In fact, the example below shows the impact that killing a VP can have on a student. The inclusion of pictures in VPs is something that the students felt they would remember more than just reading about it in a textbook. This was highlighted by the following quotes from one of the students:

"I think that having the picture of the baby makes it a bit more personal. Oh, it's a real person I'm dealing with rather than just a case in a book. You'll be sat there, or I'll be sat there at an exam with a specific question, and then you think, I can remember this because I remember seeing a case of it. And that's why I think this could potentially be such a useful tool"

12.   Current use of VPs

The feedback from the students suggests that they used the VPs in a variety of different ways. Some of the students used the VPs to practice their clinical decision making in a safe environment. This was highlighted by the following quotes from one of the students:

"I like having the opportunity to make clinical decisions and practice my clinical reasoning. Sometimes when I wasn't sure what the answer was, I'd just have a guess and then see what it said. So just sort of learning by what it told me about what was right and wrong."

Students also used the VPs as a tool for self-assessment, highlighted by the following quote from one of the students:

"I used it in the same way as you, in that I would do it without a book to test my own knowledge on the signs, symptoms, presentation, and management of the case."

The students used the VPs as an alternative to a traditional textbook. Some students used VPs as an alternative to learning the same facts that they would acquire from a textbook. Others felt that the VPs brought the facts they learnt in textbooks alive. This is highlighted by the following quotes from students:

"I used it as an alternative to my textbooks. So if I wanted to do some work, I find it more interesting than sitting just with bland textbook facts."

"I didn't sit there with a textbook next to it; I just did it to see what I could remember without the textbook."

"I don't think books always give you a very good sense of what's actually important in clinical practice. Because it's just all dry facts in books, and you can get a bit bogged in the minutia and not really realize, when a patient's in front of you, which bits are relevant at the time and which ones aren't. So I think it helps with that."

Students also found the VPs useful when preparing for their examinations, both to identify gaps in their knowledge and for general revision purposes. This is highlighted by the following quotes from students:

"I think with me – and this is just the way I would work – it'd be something I'd be doing towards whenever I had an exam or a test."

"It's also just good to remind you what you need to revise and what you already know, and so you can prioritize your learning."

13.   Future use of VPs

The feedback from the students suggests that they would indeed use virtual patients (VPs) in the future. They felt that they could use the VPs in different ways (i.e. alongside lectures and in combination with textbooks) and at different stages of their learning (i.e. before exams as a revision tool or as a learning tool over the course of a module). This was highlighted by the following quote from one of the students:

"I think I'd read some, do the theory, and then use it. I think I'd probably start to base my revision more on that kind of thing, now, whereas what I've always done before is just gone over my notes and made little revision notes. I think I'd now be much keener to move to this sort of resource over revising and just making more endless notes."

They felt that this method of learning was clinically relevant and real. This was highlighted by the following quote from one of the students:

"They're all cases that, I think, feature in our learning objectives anyway, so they're all relevant to stuff that we're going to be examined on. So it just makes a nice break and a slightly different way of working, and just to put it into practice, as well, the clinical decision-making."

The students felt that VPs were the most useful e-learning resources that they had ever used. This was highlighted by the following quote from one of the students:

"This is the only thing that I've found useful, ever. Well, semi-useful. So I think it might inspire me to use online information more, but then I'm just not used to bothering to go online to learn, so whether I'd remember to, I'm not sure. I'd probably need those email reminders or else I'd forget."

The students felt that the introduction of VPs had changed their way of learning and their study habits. In the past they felt that they were used to a certain way of learning and stuck to that routine. However, since the implementation of VPs, they had changed their way of learning. This was highlighted by the following quote from one of the students:

"I found it quite easy to get into. Because I was quite stuck in my ways from how I did my career. I was like, no, no, this is how I study and that's it. I'm still quite set in how I write my notes, but as a means of practicing I've actually found it has changed how I've worked. And I think it's something that I would definitely stick with."

14.   Suggested improvements

The students suggested two main improvements to the VPs. Firstly, they wanted to combine small investigative tasks such as simple blood tests into one group, rather than having to choose them individually. This is highlighted by the following quote from one of the students:

"Even down to the simple detail of when you order bloods"

Secondly, students wanted to have the option of doing more than one thing at a time. They felt that this would be more clinically realistic rather than exploring the consequence of each option individually, which they found frustrating. For example when given the option of multiple examinations, they would often want to choose to do more than one at the same time. This is highlighted by the following quotes from students:

"That thing of being given a list of four things and you'd do all of them, and I wish I could have just clicked all of them and to get it over there rather than having to go through it step by step."

"When it would give you a choice of four things, lots of the time you would do all of those four things. It's not like you would just choose one thing. So if you're going to do all of those things anyway, then that might be more realistic, in terms of the ability to tick several things all at once."

Finally, students wanted there to be a greater number and a wider range of VPs to be integrated into the curriculum. This is highlighted by the following quote from a student:

"I know it's probably in the early stages of this, but although it did link into my learning, I wish we had a lot more cases, because it only covered a small amount."

15.   Conclusion

Once the virtual patients were repurposed and enriched (i.e. the main outputs of the project were complete) a number of different evaluation studies were conducted with different stakeholders. The objectives of the evaluation were concerned less with the processes by which the project went about its activities, and more with gathering information on the ease of adaptation and effectiveness of VPs. The evaluation was primarily to establish the worth of what has been achieved. Given the aims of the project, it was important to capture the experiences of the students, academic staff and subject matter experts to provide data which would provide insight to inform future developments. A mixed-methods approach was employed to provide a cost-effective approach to collecting and analyzing data.

In practice the use of a virtual patient from one healthcare culture to another was an efficient use of time and resources. This study and other studies demonstrated that even though there is often a strong requirement for virtual patients each time a learning resource is used, it can still be worth the time and effort, if the learning resource has sufficient value in the learning process. This learning was the opportunity for decision-making, exploring consequences of

actions, and for safe practice. Students were be able to use these resources in a variety of different ways and learning styles, and recognized the value of a resource that improved practice. It clearly personalized their learning. Teachers and students described the outcome as highly successful.

Students believed VPs provided excellent learning, in a context which improves the making of their profession. It provided them with opportunities to practice clinical reasoning, then take decisions and explore the consequences of their decisions. VPs provided them with opportunities for learning by collaborative discussion and in tutorials, but it also provided opportunities for individual safe practice, personal revision and self-assessment.

The students described VPs as quick and easy to use, easily integrated into their study time, and available anytime, anyplace. Without ever using the phrase, students were describing the virtual patient as an excellent tool for personalized learning. There were a few improvements suggested to aspects of the VP structure, notably a request to batch the tests up in the way that clinicians would normally practice; students did not like trawling through series of test one after another. Most improvement requests were easily addressed. A student comment which was fundamental to the purpose of the MUVES project was that there were too few VPs and students wanted more.

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