Australas Phys Eng Sci Med (2015) 38:369–374
DOI 10.1007/s13246-015-0348-3

EDUCATIONAL NOTE

A virtual environment for medical radiation collaborative learning

Pete Bridge[1] · Jamie V. Trapp[1] · Lazaros Kastanis[2] · Darren Pack[2] · Jacqui C. Parker[3]

Received: 9 October 2014 / Accepted: 14 May 2015 / Published online: 22 May 2015

Abstract A software-based environment was developed to provide practical training in medical radiation principles and safety. The Virtual Radiation Laboratory application allowed students to conduct virtual experiments using simulated diagnostic and radiotherapy X-ray generators. The experiments were designed to teach students about the inverse square law, half value layer and radiation protection measures and utilised genuine clinical and experimental data. Evaluation of the application was conducted in order to ascertain the impact of the software on students' understanding, satisfaction and collaborative learning skills and also to determine potential further improvements to the software and guidelines for its continued use. Feedback was gathered via an anonymous online survey consisting of a mixture of Likert-style questions and short answer open questions. Student feedback was highly positive with 80 % of students reporting increased understanding of radiation protection principles. Furthermore 72 % enjoyed using the software and 87 % of students felt that the project facilitated collaboration within small groups. The main themes arising in the qualitative feedback comments related to efficiency and effectiveness of teaching, safety of environment, collaboration and realism. Staff and students both report gains in efficiency and effectiveness associated with the virtual experiments. In addition students particularly value the visualisation of "invisible" physical principles and increased opportunity for experimentation and collaborative problem-based learning. Similar ventures will benefit from adopting an approach that allows for individual experimentation while visualizing challenging concepts.

Keywords Radiotherapy · Medical imaging · Radiation physics · Education · Collaboration · Virtual reality

✉ Pete Bridge
peter.bridge@connect.qut.edu.au

[1] School of Clinical Sciences, Queensland University of Technology, George Street, Brisbane, Australia

[2] End to End Visuals, Brisbane, Australia

[3] Princess Alexandra Hospital, Woolloongabba, Australia

Introduction

As an essential component of their training, Medical Radiation Science students undertake study of Radiation Safety and Radiation Protection to engender an understanding and respect for radiation safety. Essential physical principles within this topic include the Inverse Square Law, Half-Value Thickness and X-ray scatter processes. Traditionally teaching of these principles is augmented with experimental sessions on real X-ray machines or radioactive sources to reinforce the practical application of the theory. Unfortunately increasing pressure on resource-intensive radiation facilities frequently restricts access. Virtual Reality software simulation has been used successfully in a range of professions to provide a cost-effective and safe learning environment in which students can practice essential and challenging skills [1–4]. In this work a software-based environment was developed, which is capable of providing practical training in medical radiation principles and safety. The Virtual Radiation Laboratory (VRL) application was developed to provide students with the opportunity to conduct virtual experiments using simulated diagnostic and radiotherapy X-ray generators. The experiments aimed to provide students with understanding of the radiation safety aspects of their work as well as opportunities to develop their collaborative working skills and better prepare them for clinical practice.

Methods

The Quest 3D (Act-3D, B.V) real-time 3D graphics engine was used to create a series of interactive simulated environments including radiation laboratory benches, kilovoltage imaging room and linear accelerator bunker as seen in Figs. 1 and 2. Calculations for the inverse square law, half value thickness and radiation scatter were derived from experimental data and implemented for each experiment with output from user interaction calculated in real-time. The experiments were designed to facilitate collaborative working in small teams using collaborative learning spaces. Piloting with volunteers from the previous cohort of students informed software development. The main evaluation phase was conducted after a full cohort of students (n = 126) had received teaching using the new software and sought feedback concerning the perceived value and limitations of the application. The aims of this evaluation phase were to monitor the impact of the software on students' understanding, satisfaction and collaborative learning skills and also to determine potential further improvements to the software and guidelines for its continued use. Ethical approval for the evaluation was provided by the University Research Ethics Committee as part of a wider project into Course Improvement. Students were asked to complete an anonymous online survey consisting of a mixture of six Likert-style questions (seen in Table 1) and five short answer open questions seeking thoughts on advantages, disadvantages, potential improvements, use of the resource and any additional comments. Students were required to submit the survey as part of the Unit evaluation process, although they were advised that question completion was voluntary and all questions allowed for a "No Answer" response. Anonymity was assured by the Virtual Learning Environment survey tool.

Statistical analysis

All 126 student responses were collated and independent analysis of the qualitative data was performed by two researchers to minimise the effect of bias. A mixture of descriptive statistical tools (such as relative response rates and summary tools) for the Likert responses and simple thematic analysis (coding and grouping) techniques for the open questions was utilised. Correlation analysis of the quantitative data was performed using the Pearson product-moment correlation coefficient.

Results

A total of 126 responses were provided by the student cohort with a question answer rate of 99.3 % for the 6 Likert responses. The 5 open answer questions attracted a lower response rate ranging from 40 to 55 %. Table 1 summarises the results of the Likert questions where 80 % of students reported increased understanding of radiation protection principles, 72 % enjoyed using the software and 87 % felt that the project had facilitated collaboration within small groups. There were few disagreements with the positive Likert stems. Most of the students identified themselves as experienced computer users with only 6.5 % self-assessing as inexperienced. Correlation analysis demonstrated only weak or negligible correlation between computer experience and enjoyment, ease of use and understanding (all $r < 0.25$). Only the enjoyment correlation was statistically significant ($p = 0.009$). Themes arising from the qualitative analysis of the open answer questions triangulate well with the quantitative data with many students providing comments about the ease and enjoyment of

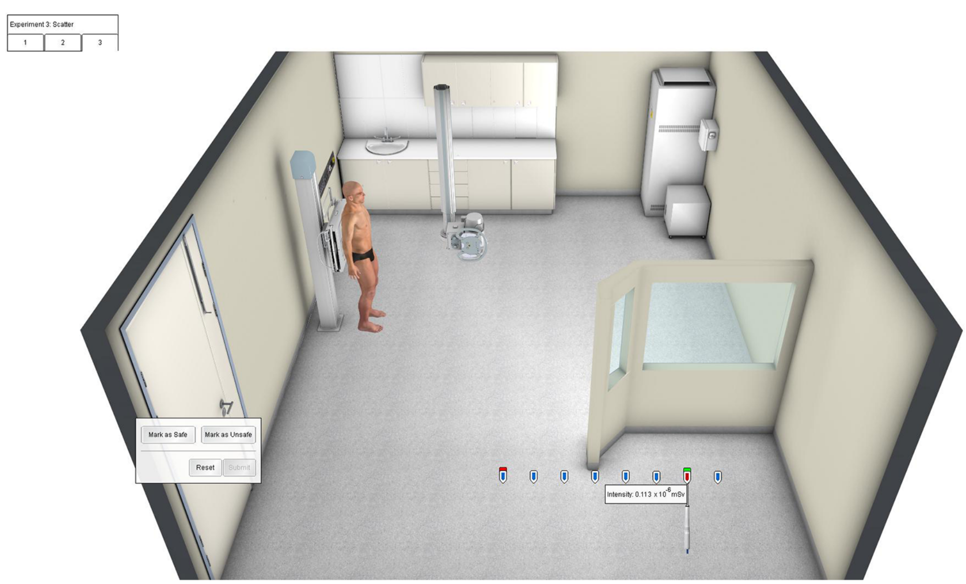

Fig. 1 Screenshot of the diagnostic virtual radiation environment

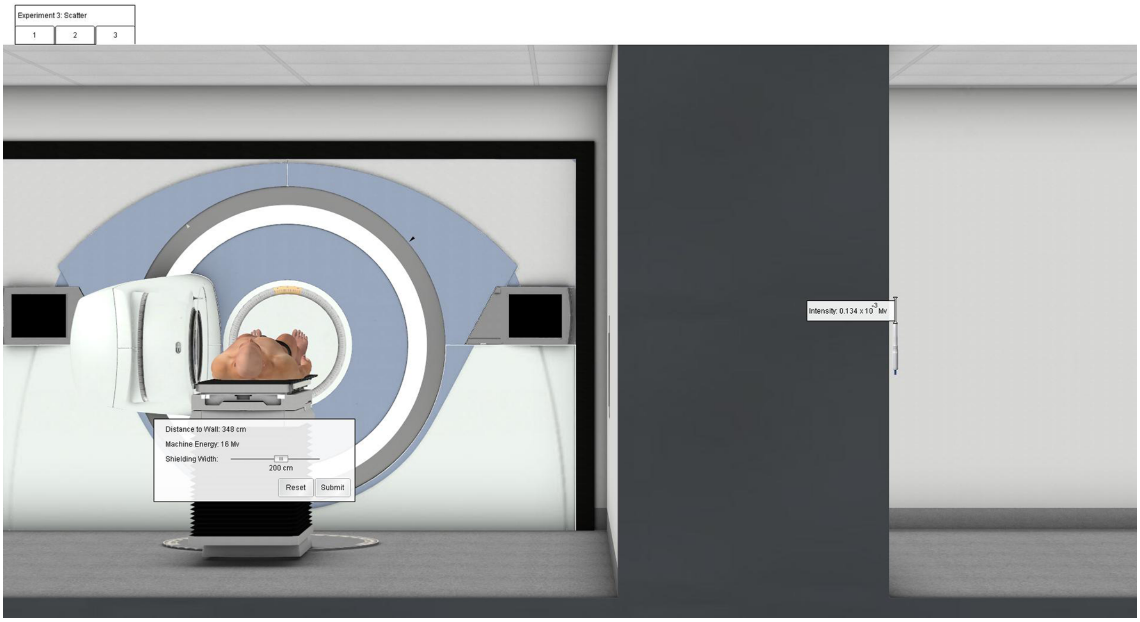

Fig. 2 Screenshot of the radiotherapy virtual radiation environment

Table 1 VRL Evaluation Results

Likert stem	Percentage response					
	AS	S	N	D	DS	NA
I consider myself to be experienced with computers/gaming	28	45	20.5	5.5	1	–
I enjoyed using the Virtual Radiation Lab (VRL) software	12	59.5	24	4.5	–	–
I found the VRL easy to use	17.5	65	13	3	–	1.5
The VRL helped increase my understanding of radiation protection principles	15	65	14	5	1	–
The VRL was used to good effect in the workshop session	17.5	61	13.5	4.5	1	2.5
The VRL facilitated collaboration within small teams	31.5	55	12	1.5	–	–

AS agree strongly, *A* agree, *N* neither, *D* disagree, *DS* disagree strongly, *NA* not answered

use, facilitation of understanding and improved collaboration arising from the application. The main themes arising in the qualitative feedback comments related to efficiency and effectiveness of teaching, safety of environment, collaboration and realism as seen in Figs. 3 and 4. Further analysis of these themes follows in the Discussion section. In terms of resource implications, the software enabled large group teaching which reduced the number of group bookings from 7 to 2. For the 4 h of practical allocated per student this resulted in a time saving of 24 h.

Discussion

Most of the students identified themselves as experienced with software which is unsurprising for the modern undergraduate cohort [5]. The main themes arising in the

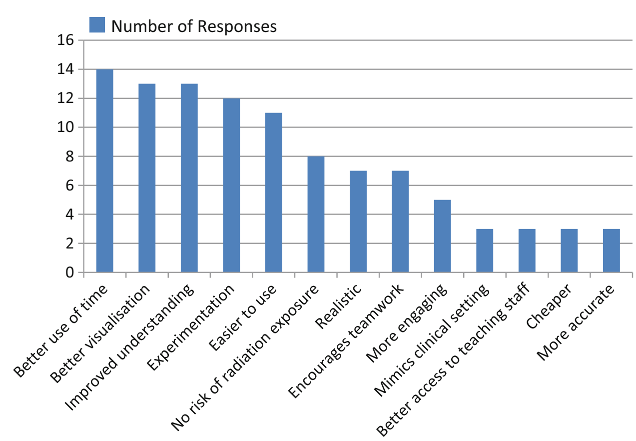

Fig. 3 Advantages of the VRL

qualitative feedback comments related to efficiency and

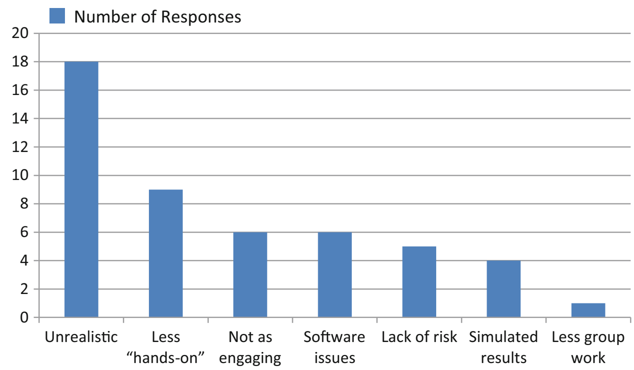

Fig. 4 Disadvantages of the VRL

effectiveness of teaching, safety of the environment, facilitation of collaborative learning and perceived realism. Further comments relating to best practice in use of the resource and potential improvements to the resource also form the basis for recommendations for future use. Representative comments supporting the discussion themes are presented in Table 2.

Efficiency

When students were asked what were the potential benefits arising from the VRL the most commonly arising responses

Table 2 Indicative comments supporting discussion themes

Feedback theme	Indicative comments
Efficiency	"Saves time while maintaining similar learning outcomes as real lab practicals"
	"It's easier to set up, no fussing around with real sources of radiation etc"
	"You get results more efficiently, which means spending more time on why things happened and answering the questions which is where you learn"
Cost effective	"Having students working via a computer program allows staff to move easily among the groups to help, and it is easier to coordinate group activities amongst yourselves as we are not all spread out in labs"
	"It's probably faster and cheaper to run than being in a lab"
Enjoyment	"Very fun to play with"
	"I thoroughly enjoyed the learning experience and felt like it saved me lots of time"
	"Loved the practical and helped me consolidate much of the theory. Made more sense looking at it virtually and loved how you could experiment"
Understanding	"It shows the pathway of X-ray beams, which help with the understanding of ways to promote radiation safety"
	"Able to see what you normally can't e.g. scatter radiation, so helps understanding"
	"I found this lab helpful in understanding the concepts of Radiation Safety because the computer program used helped me to visualise what we were studying"
Interactivity	"Computer program based workshop does not deliver same interactiveness"
	"I don't remember things that I do on a computer as much as I do with things that I do with my own hands"
Collaboration	"The greatest advantage of the virtual lab was that the workspace facilitated group work and strongly encouraged all group members to participate and input their thoughts and ideas. In a real lab, the workspaces are generally designed for individual work"
Safe environment	"You also won't be exposed to any radiation using the VRL as opposed to actually being in the real practical labs"
	"Not being exposed to the potential risks…and learning how to mitigate"
	"I don't get the feeling of a laboratory and so due to the simulation environment I may take the exercise less seriously"
Realism	"I thought it was just like the real thing"
	"It allowed you to see the setting in which you will be working in in your future practice"
	"I think the VRL system allows you to easily make the connection between radiation protection and safety and our potential places of employment (i.e. our course of study). I sometimes find that real lab practicals are not as relevant to the actual job we will undertake"
	"Can't simulate everything which occurs in reality"
	"The VRL does not have the same atmosphere as a real lab which is a disadvantage"
	"The disadvantages may be that you can't experience what it's really like to be in the real lab practicals. I think actually being in the room yourself can make you learn more and engage in more of what you're doing. Experiencing it in real life is what counts and looking at the computer screen or pictures cannot do justice"

related to better use of time. Students could perceive the efficient nature of the software simulation in terms of the University resources and staff time as well as their own time. They also commented that the format allowed for better access to teaching staff and was likely to be more cost effective. From an academic perspective, as with other published findings [2, 6], the simulation led to a more efficient use of resources and personnel arising from reduced contact hours and use of collaborative learning spaces rather than resource-intensive radiation laboratories. This manifested itself in a reduced impact on specialist laboratory timetabling.

Effective teaching

While gains in efficiency are valuable at an institutional level, these are of little value unless there is a positive impact on teaching and learning. Student feedback was highly positive in relation to the impact of the VRL on understanding of the topic with 80 % of students reporting that the project had increased their understanding of radiation protection principles. Along with increased understanding, 72 % enjoyed using the software; a finding common to many Virtual Reality applications [1, 7]. In addition, however, qualitative analysis suggested students particularly relished the increased opportunity for easy experimentation.The visualization of "invisible" physical principles was another significant benefit perceived by the students and it was clear that this had led to increased understanding in much of the cohort. Conversely some students felt that the VRL provided a less engaging environment citing the reduction in "hands-on" time as a contributing factor. There is a real danger that understanding of processes is replaced with a series of button clicks and such resources must be used in such a way as to limit this. It is also important to remember that this conflicting data reinforces the acknowledged variety in learning styles within modern undergraduate cohorts [8] and suggests that a mixed approach combining both virtual and real learning environments is most likely to satisfy these diverse needs.

Collaboration

A key finding from the evaluation was that 87 % of students felt that the project facilitated collaboration within small groups. Although the radiation laboratory format also utilised a group format this was largely due to resource availability rather than a pedagogical approach. The various group tasks and requirement for discussion on the experimental findings along with the ability to experiment with different settings naturally encouraged teamwork and this was echoed in the qualitative comments. For this cohort of students working towards multi-disciplinary teamwork-orientated professions [9] this is a most encouraging finding.

Safe environment

There were many comments from students regarding the enhanced facilitation of experimentation with students enjoying learning from mistakes and trial and error in a manner that would be discouraged in a radiation laboratory with live sources or expensive equipment. The benefits of the "safe" environment provided by simulation solutions have long been acknowledged in the literature [3, 10], although this is usually related to patient safety. In this paper it was interesting to see how simulation could potentially improve safety for learners too. Given the focus of the academic unit, it was reassuring to see students appreciating the potential dangers of radiation in their feedback (although it should be stated that students are not, in fact, routinely exposed in the radiation laboratory). Despite this, some students did cite the lack of risk as a potential disadvantage of the application with a reduction in learning about working safely with live sources. Clearly a balance must be struck between the learning arising from potentially dangerous situations and the benefits of an experimental problem-based learning approach.

Realism

The effectiveness of simulated teaching environments is often linked with the immersion or the sense of realism engendered [11]. Although this was a relatively low fidelity simulation students appreciated the simulated clinical environments and several responses cited the realism and close approximation to clinical practice as benefits of the VRL. There were a large number of students, however, that judged the simulation to be unrealistic, lacking the element of danger or hands-on practice. There was a clear need for students to experience the real clinical situation. This echoes findings from other pre-clinical simulation studies [7, 12] where the value of simulation in an academic environment lies in better preparing the students for real life clinical experience. It is recommended that this is emphasised in the workshop's introduction session.

Facilitation

Student feedback strongly suggested that, as with many academic activities, successful learning depended to a great extent on the attitude of their tutors. While there is little that can be done about individual approaches to tutoring results from this study suggest that there is value in allowing multiple tutors to interact with the students in the collaborative learning space where they can each provide their own insight and experience. Student comments also suggested that introductory material provide a clearer message about the aims and outcomes of the experiments. Within the experiments themselves, however, there were mixed messages about the levels of support required with some students requesting further instruction and others feeling "spoon-fed". Again this mixture of expectations reinforces the need for a mixed methods approach to provision of resources. When students were asked for suggestions to improve use of the resource there were several comments requesting additional individual access both on and off campus to the application. This has the potential to improve self-directed learning and encourage learner autonomy.

Limitations

There are several limitations associated with this study. As it was a developmental project there were still some software bugs present during the evaluation phase. These included some issues with time lag, a requirement for an additional factor to be added and some user interface confusion. Student comments from the evaluation are currently informing ongoing improvement to the resource as well as designing introductory and support materials. It is likely, however, that the developmental nature of the software could have led to perceived problems with realism and ease of use. In terms of the evaluation it must be acknowledged that in the absence of a control arm the student evaluation is hard to compare directly with the "real" radiation laboratory experiments. This can be ameliorated to some extent within this cohort as they all undertook a similar format of experiment in the previous semester. The anonymous nature of the survey tool and the use of an independent researcher should reduce interpretation bias but it should be acknowledged that the software development and evaluation was funded by a University Teaching and Learning Grant aimed at improving the student learning experience.

Conclusion

This work has demonstrated the value of software simulation for facilitating experimentation aiming to enhance understanding of radiation principles. Facilitation using a range of tutors can enhance the learning and where possible unsupervised access can be provided for students wishing to experiment further. Staff and students both report gains in efficiency and effectiveness associated with the virtual experiments. In addition students particularly value the visualisation of "invisible" physical principles and increased opportunity for experimentation and collaborative problem-based learning. Similar ventures will benefit from adopting an approach that allows for individual experimentation while visualizing challenging concepts.

Acknowledgments This work was funded by a Queensland University of Technology Teaching and Learning Grant. The authors wish to acknowledge the support of Shimadzu and Brisbane Private Imaging for their assistance with software modelling.

References

1. Bridge P, Appleyard RM, Ward JW, Philips R, Beavis AW (2007) The development and evaluation of a virtual radiotherapy treatment machine using an immersive visualisation environment. Comput Educ 49:481–494
2. Kilmon CA, Brown L, Ghosh S, Mikitiuk A (2010) Immersive virtual reality simulations in nursing education. Nurs Educ Perspect 31:314
3. Kulcsár Z, O'Mahony E, Lövquist E et al (2013) Preliminary evaluation of a virtual reality-based simulator for learning spinal anesthesia. J Clin Anesth 25:98
4. Pinto ML, Sabater JM, Sofrony J, Badesa FJ, Rodriguez J, Garcia N (2010) Haptic simulator for training of total knee replacement. Paper presented at IEEE
5. Kanthan R, Senger JL (2011) The impact of specially designed digital games-based learning in undergraduate pathology and medical education. Arch Pathol Lab Med 135:135–142
6. Bridge P, Gunn T, Kastanis L et al (2014) The development and evaluation of a medical imaging training immersive environment. J Med Radiat Sci 61:159–165
7. Fagan M, Kilmon C, Pandey V (2012) Exploring the adoption of a virtual reality simulation. Campus-Wide Inf Syst 29(2): 117–127
8. Williams B, Brown T, Winship C (2013) Learning style preferences of undergraduate paramedic students: a pilot study. J Nurs Educ Pract 3:51
9. Koo K, Di Prospero L, Barker R et al (2014) Exploring attitudes of Canadian radiation oncologists, radiation therapists, physicists, and oncology nurses regarding interprofessional teaching and learning. J Cancer Educ 29:350–357
10. Sandra LM, Helen M (2012) Simulation in surgical education. Clin Colon Rect Surg 25:156–165
11. Flinton D, White N (2009) Preliminary findings on the virtual environment for radiotherapy training (VERT) system: simulator sickness and presence. J Radiother Pract 8:169–173
12. Nisbet H, Matthews S (2011) The educational theory underpinning a clinical workbook for VERT. Radiography 17:72–75