J Med Syst (2015) 39: 97
DOI 10.1007/s10916-015-0283-6

EDUCATION & TRAINING

Computer Applications in Health Science Education

Juan A. Juanes[1] **· Pablo Ruisoto**[1]

Received: 15 November 2014 / Accepted: 20 July 2015 / Published online: 8 August 2015

Abstract In recent years, computer application development has experienced exponential growth, not only in the number of publications but also in the scope or contexts that have benefited from its use. In health science training, and medicine specifically, the gradual incorporation of technological developments has transformed the teaching and learning process, resulting in true "educational technology". The goal of this paper is to review the main features involved in these applications and highlight the main lines of research for the future. The results of peer reviewed literature published recently indicate the following features shared by the key technological developments in the field of health science education: first, development of simulation and visualization systems for a more complete and realistic representation of learning material over traditional paper format; second, portability and versatility of the applications, adapted for an increasing number of devices and operative systems; third, increasing focus on open source applications such as Massive Open Online Course (MOOC).

Keywords Visualization · Open source · OS · MOOC

This article is part of the Topical Collection on *Education & Training*

✉ Pablo Ruisoto
ruisoto@usal.es

Juan A. Juanes
jajm@usal.es

[1] University of Salamanca, Salamanca, Spain

Technologies of information and communication (TICs)

New technologies of information and communication (TICs) are part of deep sociocultural transformations in health education regarding the need to manage an increasing amount of new information. According to UNESCO, the integration of new technologies in education should focus on the development of new learning environments, enhancing communication, and promoting distance learning.

Two approaches should be distinguished: first, learning about TICs, which refers to those experiences that aim to obtain knowledge about technologies as an end in itself; second, learning with TICs, which see TICs as a means to improve our knowledge in other areas such as health education.

Virtual training and learning campuses are the result of new technology. New wireless technologies open the possibility to access large amounts of information and learn when we want, in a world full of knowledge available anywhere. Therefore, virtual training is growing in response to and as a demand to the new needs of professionals in an environment that requires constant adaptation. This permanent need to update knowledge and skills is defining the new educational models in medical training, with a change in perspective and an exponential increase in online education according to the current needs of the information society.

In medical contexts, those virtual environments can offer medical students and practitioners a series of advantages: implementation in the workplace, immediacy response, schedule and space flexibility. It will probably respond faster and more effectively than other traditional teaching systems.

Devices and digital environments based on clinical simulation can play an important role in acquiring competences and clinical skills, since they are able to reproduce the real environment that students will face in the future, thus having a more active and effective learning process. Much of the software offered in medical training has been mainly designed for self-learning and for the acquisition of certain abilities and skills. The generation of a good virtual environment, well addressed, allows sometimes doing hardly feasible activities in the classroom, promoting student critical thinking and actively participating in their own learning process. In the following years, we will witness an even greater development in the use of simulations in medical training.

In fact, the integration of new technologies in the classroom is one of the keys to success in health education and recent research is focusing on measuring the impact of using new technologies. Readings, online assignments and lectures, and other interactive materials prepare students for in-class discussions and are perceived as more attractive than traditional learning materials [1, 2].

A whole new generation in health science education is being increasingly trained in new technologies, promoting innovation and communication [3–5]. The application of computer technologies in health science education broadens the action and intercommunication possibilities between teachers and students, allowing access to new means of exploration and representation, together with new ways to access knowledge through a variety of tools: powerful body structure visualization, multimedia imagery, computer simulations, stereoscopic visualization, virtual and augmented reality techniques, computer platforms for resource and document storage and mobile devices. Using technologies regardless of space and time in digitalized information transmission is nowadays one of the greatest technological, scientific and cultural revolutions in our society.

The use of technological resources can encourage independent or group learning experiences, a mayor stimulus and additional support to classes; making learning less formal through complementary tools that enrich and improve the teaching system. Health science education has become a more globalized process, so we should open ourselves and look outward for new horizons in education. It is necessary to pursue new educational models with a technological basis, that provide health science professionals the necessary tools to develop their subsequent work with the professional capacity that is nowadays required in complex organizations.

A full integration of new information technologies in health science education remains a challenge. Access to new digital tools is not enough and a better knowledge of the possibilities is further needed. The learning model based on the handling of technological tools is being introduced into our teaching systems little by little, changing traditional education and gaining ground in the use of technological devices and procedures at our disposal; it is trying to build a bridge between technology based training and the real world.

The application of knowledge resulting from technological advances in science has changed the way in which information is transmitted. Within health science in particular, it has represented a series of constant technological developments that have resulted in the transformation of medical training patterns. But applying technology in training is not only based on the instrumental domain of some computer equipment, but in the capacity to design teaching resources in health science with the objective of reaching goals that we would have set for ourselves in any field. Therefore, as shown in the Council for Educational Technology, "Educational Technology is the application of knowing systems and techniques to improve human learning", we will probably witness an even greater development of innovative technology and its use in medical education within our country in the coming years.

Once more in the context of medicine, one of the main challenges of the teaching and learning process is to combine the training needs with the demands of the professional activity the student will face. For this reason, it is important to design specific activities and tasks adapted to the needs of the professional practice.

Finally, TICs are instruments that permit the design of an innovative teaching methodology, which is a complex process where not only teachers participate, but the institution as well; that is why both teachers and universities have to adapt the teaching and learning processes with the aim of accentuating the active implication of our students in their learning process. In order to do this, they must introduce the technological tools that today's society imposes and that new students are used to. The use of technologies in teaching has become one of the basic pillars in university education within health science. The aim of this special issue is to exemplify how technology is increasing its presence in health science education in order to familiarize professionals with the use and possibilities of new technologies. A general view of experiences in the field will be provided. In addition, current technological tools and their possibilities in health science education will be introduced for both teachers and researchers.

The technological application development with teaching purposes in health science is paying increasing attention to mobile phones, smartphones and tablets due to their portability, economic accessibility and internet access, maximizing the dissemination and availability of developed applications. These changes in health science teaching pose a challenge for teachers and institutions when designing, developing, implementing and evaluating these technological applications, as well as an effort on behalf of students to adapt. Nowadays, a growing number of studies have directed their attention to evaluating the effectiveness of these applications with increasingly sophisticated designs. The results are encouraging and signal a promising future for the development of computer applications in this field.

3D visualization and simulation applications

The first feature of the most successful health science innovations is to focus on visual information display, developing powerful simulation and 3D visualization applications, specifically in complex medical fields such as neuroscience [6–8]. The visualization of 3D anatomical models creates a more realistic and precise visual perspective of different body structures than conventional medical imaging from different 2D diagnostic modalities. Volumetric visualization provides more complete information when defining the macroscopic morphological features and spatial relationships of body structures like bones or muscles. Moreover, 3D models visualized in simulation contexts increase the possibilities of their global morphological assessment and reduce complications in surgical interventions. This advantage is especially important in planning virtual surgical approaches where precise delimitation in the intervention of body structures is required. In recent years, it has been possible to combine volumetric visualization with virtual reality systems that allow the surgeon to browse through 3D reconstructed body structures or even touch them, including resistance and texture simulation of various tissue surfaces or haptic feedback technology, vital when detecting tumors.

The use of visual resources in three-dimensional format is an attractive and innovative method in teaching and student learning, as well as a reusable and useful tool to encourage and motivate learning in any discipline within health science. 3D models have enhanced and renewed traditional pedagogical system resources, offering a more complete vision of anatomical body structure characteristics. These resources uphold the emphasis on using visual aids as key elements, beyond simple textbook illustrations. The generation of three-dimensional images developed with the help of 3D reconstruction commercial software, is part of a new pedagogical visual strategy, which allows teaching content activation and review to improve the understanding of body structures.

The comprehension capacity of body structures is closely related with the ability to visualize them. Traditionally, the different diagnostic imaging modalities have shared a common limitation, the two- dimensional features of their representations. The visualization and interpretation of human body images from imaging techniques, has an added difficulty due to its complexity and individual morphological differences (biological variation). Learning human anatomy, one of the most relevant health science disciplines, requires the understanding of morphological features and spatial relationships in proximal areas amongst the different body structures. Thus, volumetric visualization of these structures optimizes the presentation of complex information within morphological images obtained from diagnostic imaging techniques. Not only is the synthetic visualization capacity improved, but also the degree of interactivity and realism, overcoming the inherent restrictions of 2D traditional representations.

Considering this important aspect of spatial vision, many technological procedures have emerged that allow 3D body image reconstruction from sections obtained through diagnostic imaging modalities. The 3D reconstruction process or volumetric generation is the acquisition of one or more series of tomographic images, the posterior segmentation or identification and labelling of anatomical body structures, the extraction of contours/surfaces in adjacent transverse sections and the rendering of the 3D model.

Technology benefits learning by enhancing the comprehension of complex contents as in the case of neuroanatomy and the level of engagement with the learning materials [9, 10].

The development and implementation of virtual learning environments can, overcome traditional limitations associated with physical classrooms by themselves, going beyond the use of a computer as a simple tool and turning it into a virtual classroom. Simulations are acknowledged as an emerging future modality because with technological development more emphasis can be made on skills and clinical reasoning. Simulations try to reproduce situations that are as real as possible, offering a series of advantages and guaranteeing patient safety. This very effective type of training has been institutionalized in other professions and medical education has to aim for the advantages it represents.

These kind of training activities offer educational advantages; they offer safety in the face of mistakes made in high risk technique training, a reduced and less dangerous cost than working in real environments and they can also help understand the processes.

Nevertheless, there are still many issues regarding quality and result evaluation in this type of training applied in real practice, and although the idea has great development potential for a more effective medical training, further progress in this direction is still needed.

There is a great disparity in technological procedures and environments applied to health science education, as a complement to teaching systems. Thus, it is important to consider some requirements that meet teaching expectations. Amongst these requirements we emphasize the following: accessibility: ability to locate and have access to training materials from a remote location and distribute them on the Internet; interoperability: ability to use materials in different platforms and locations; durability: ability to withstand technological development without re-encoding or redesigning materials thoroughly; reusability: flexibility to include training components in different contexts and applications, for example in different training activities; and cost-effectiveness: time and cost reduction in teaching.

Mobile applications

The second feature of the most successful applications (is) available for a wide range of OS and devices such as mobile phones or tablets, enhancing (their) portability and versatility [11–19]. The characteristics of these mobile devices encourage the implication of students in learning through the direct interaction with teaching contents, making them an excellent platform in university education. The use of portable devices is associated with a change in information and communication search habits amongst users. Little by little, new applications are being developed, (better) adapted to curricular situations and teaching plans. Nowadays, it seems difficult to conceive a society where mobile devices are not important tools in our everyday life, both professionally and leisurely.

A good technological procedure in medical training needs to be user friendly. Procedures should not be complex or else they create user insecurity. Doubts regarding specific processes and tasks should be solved quickly and precisely, maintaining student attention.

Moreover, with the use of technologies in training, the interaction amongst participants and the role of the tutor who designs its application are key in the success of the teaching activity and in getting positive results. That is why computer programs used in training should look for models that facilitate learning. We must also seek student interest, introducing resources that promote learning. Accordingly, the design of the technological application we work with should call attention to the most relevant interest points, be practical and always look for activities that facilitate learning and student motivation. For these means of communication to be effective, they require different types of interactions and spaces with several formality levels, some moderate and guided and others not, allowing the development of different interaction levels amongst users. In this special issue we present a series of interesting and useful technology based projects in health science education. In them, the transformation of medical training can be seen with the introduction of new technologies that entail the use of more modern technology in teaching, specially using mobile devices.

Open source applications

The third feature of the most successful applications in health science education is the increasing attention to applications based on an open source approach [20–27]. It is still one of the heated debates regarding the development of new technologies and revolves around the use of open source or proprietary applications. However, in general, open source is associated with accessibility or transparency in the process and final product and collaboration or orientation to share knowledge among peers. These applications also increase the likelihood of creative solutions, imply a lower degree of power concentration and therefore are more democratic. In fact, although they do not have to be free, their price is lower than proprietary applications.

As an example of the implication for this open source approach has we should mention the MOOC as a potential framework to deliver and gain knowledge over a wide range of disciplines [28–32]. One of the main advantages in the use of these technologies, from a functional standpoint, is the possibility to learn anytime and anywhere, taking into consideration the fast interaction with the computer application, the cost is not too high, more internet accessibility, more portability, and the possibility of a more collaborative (forming groups, sharing answers, providing information, etc.) as well as exploratory learning (learning on the field, exploring, experimenting and applying while learning a specific topic).

Conclusion

In the future, the gradual miniaturization of computer components will contribute to enhance portability of powerful applications for smartphones and tablets, will be able to make complex math calculations, manage large databases faster, to name only a few of its functions. The main consequence is the opportunity to develop new applications and pedagogical strategies, which optimize the teaching and learning process in health science disciplines but is not limited to them. In sum, we can expect an increasing number of simulation and visualization systems in health science, available through smaller, faster, and more powerful devices such as mobile phones and tablets, developed as Open Source applications, presented as stand-alone applications or as tools for MOOC.

Conflict of Interest Nothing to declare.

References

1. Ruisoto, P., Juanes, J., and Prats, A., Enhancing neuroanatomy education using computer-based instructional material. *Comp Hum Behavior* 31:446–452, 2013. doi:10.1016/j.chb.2013.03.005.
2. Ruisoto, P., Juanes, J. A., Contador, I., Mayoral, P., and Prats-Galino, A., Experimental evidence for improved neuroimaging interpretation using threedimensional graphic models. *Anat Sci Ed.* 5: 132–137, 2012. doi:10.1002/ase.1275.
3. Lau, F., and Bates, J., A review of e-learning practices for undergraduate medical education. *J Med Syst* 28(1):71–87, 2004.
4. Martínez-Pérez, B., de la Torre-Díez, I., and López-Coronado, M., Privacy and security in mobile health apps: a review and recommendations. *J Med Sys* 39:181–89, 2014.
5. Lin, C. F., Mobile telemedicine: a survey study. *J Med Syst* 36:511–20, 2012.
6. Juanes, J. A., Ruisoto, P., Prats-Galino, A., Framiñán, A., and Riesco, J. M., Computed anatomical modelling of the optic

pathway and oculomotor system using magnetic resonance imaging. *J Neuroradiol* 41(3):168–76, 2014. doi:10.1016/j.neurad.2013.06.005.

7. Nowinski, W., and Chua, B. C., Stroke atlas: a 3D interactive tool correlating cerebrovascular pathology with underlying neuroanatomy and resulting neurological deficits. *Neuroradiol J* 26(1):56–65, 2013.
8. Nowinski, W. L., and Chua, B. C., Bridging neuroanatomy, neuroradioloy and neurology: three-dimensional interactive atlas of neurological disorders. *Neuroradiol J* 26(3):252–62, 2013.
9. Lobb, A., and McDonell, S., Technology can improve public health education. *American Journal of Public Health* 99(3):391–391, 2009.
10. Goldman, R. H., Cohen, A. P., and Sheahan, F., Using seminar blogs to enhance student participation and learning in public health school classes. *Am J Public Health.* 98:1658–1663, 2008.
11. Aungst, T. D., Clauson, K. A., Misra, S., Lewis, T. L., and Husain, I., How to identify, assess and utilise mobile medical applications in clinical practice. *Int J Clin Pract* 68(2):155–62, 2014. doi:10.1111/ijcp.12375.
12. Aungst, T. D., Medical applications for pharmacist using mobile devices. *Ann Pharmacother* 47(7–8):1088–95, 2013. doi:10.1345/aph.1S035.
13. Moodley, A., Mangino, J. E., and Goff, D. A., Review of infectious diseases applications for iPhone/iPad and android: from pocket to patient. *Clin Infect Dis* 57(8):1145–54, 2013. doi:10.1093/cid/cit455.
14. Zaki, M., and Drazin, D., Smartphone use in neurosurgery? APP-solutely! *Surg Neurol Int.* 5:113, 2014. doi:10.4103/2152-7806.137534.
15. Brewer, A. C., Endly, D. C., Henley, J., Amir, M., Sampson, B. P., Moreau, J. F., and Dellavalle, R. P., Mobile applications in dermatology. *JAMA Dermatol* 149(11):1300–4, 2013. doi:10.1001/jamadermatol.2013.5517.
16. Bhatia, A. C., Itss right there in your hand: underuse of mobile applications in dermatology. *JAMA Dermatol* 149(11):1305, 2013. doi:10.1001/jamadermatol.2013.6641.
17. Ellaway, R., The informal and hidden curricula of mobile device use in medical education. *Med Teach* 36(1):89–91, 2014. doi:10.3109/0142159X.2014.862426.
18. Boruff, J. T., and Storie, D., Mobile devices in medicine: a survey of how medical students, residents, and faculty use smartphones and other mobile devices to find information. *J Med Libr Assoc* 102(1):22–30, 2014. doi:10.3163/1536-5050.102.1.006.
19. Székely, A., Talanow, R., and Bágyi, P., Smartphones, tablets and mobile applications for radiology. *Eur J Radiol* 82(5):829–36, 2013. doi:10.1016/j.ejrad.2012.11.034.
20. Borton, J. K. S., Oakes, M. A., Van Wyk, M. E., and Zink, T. A., Using PsyScope to conduct IAT experiments on macintosh computers. *Behavior Research Methods* 39(4):789–796, 2007.
21. Peirce, J. W., PsychoPy - psychophysics software in python. *J Neurosci Methods* 162(1–2):8–13, 2007. doi:10.1016/j.jneumeth.2006.11.017.
22. Peirce, J. W., Generating stimuli for neuroscience using PsychoPy. *Front Neuroinform* 2(2):10, 2009. doi:10.3389/neuro.11.010.2008.
23. Mathôt, S., Schreij, D., and Theeuwes, J., OpenSesame: an open-source, graphical experiment builder for the social sciences. *Behavior Research Methods* 44(2):314–324, 2012. doi:10.3758/s13428-011-0168-7.
24. Rosset, A., Spadola, L., and Ratib, O., OsiriX: an open-source software for navigating in multidimensional DICOM images. *Journal of Digital Imaging* 17(3):205–216, 2014.
25. The Visualization Toolkit (VTK): http://public.kitware.com/VTK/, Accessed March 18, 2015.
26. The Insight Segmentation and Registration Toolkit (ITK): http://itk.org/, Accessed March 18, 2015
27. Fedorov, A., Beichel, R., Kalpathy-Cramer, J., Finet, J., Fillion-Robin, J.-C., Pujol, S., Bauer, C., Jennings, D., Fennessy, F., Sonka, M., Buatti, J., Aylward, S. R., Miller, J. V., Pieper, S., and Kikinis, R., 3D slicer as an image computing platform for the quantitative imaging network. *Magn Reson Imaging* 30(9):1323–41, 2012.
28. Gyles, C., Is there a MOOC in your future? *The Canadian Veterinary Journal* 54(8):721–724, 2013.
29. Liyanagunawardena, T. R., and Williams, S. A., Massive open online courses on health and medicine: review. Eysenbach G, ed. *Journal of Medical Internet Research* 16(8), e191, 2014. doi:10.2196/jmir.3439.
30. Liyanagunawardena, T. R., Adams, A. A., and Williams, S. A., MOOCs: a systematic study of the published literature 2008–2012. *International Review of Research in Open and Distance Learning* 14(3):201–227, 2013.
31. Hoy, M. B., MOOCs 101: an introduction to massive open online courses. *Med Ref Serv Q* 33(1):85–91, 2014. doi:10.1080/02763869.2014.866490.
32. Paton, C., Massive open online course for health informatics education. *Healthcare Informatics Research* 20(2):81–87, 2014. doi:10.4258/hir.2014.20.2.81.