Research Review Paper ■

Information Technology in Medical Education

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Abstract. The advancements and innovations of information technology offer a number of modes of delivery of medical knowledge and skills. As an education tool, e-learning should satisfy and maintain educational aims, be flexible and enable collaboration and communication between students and teachers. It should be student-oriented and centered towards specific users' needs. The virtual patient is a specific clinical examination tool that may be used efficiently for training and assessment. Systematic literature reviews suggest that e-learning is as effective as traditional educational methods, but may offer additional benefits. The article includes a SWOT analysis of e-teaching and e-learning in medical education and identifies the infrastructure required for supporting e-learning within medical education.

Informacijska tehnologija v medicinskem izobraževanju

Izvleček. Napredek in iznajdbe na področju informacijske tehnologije nudijo številne možnosti za prenos medicinskega znanja in spretnosti. E-učenje mora kot izobraževalno orodje ustrezati učnim ciljem in zagotavljati njihovo doseganje, biti mora prilagodljivo in omogočati sodelovanje in sporazumevanje med študenti in učitelji. Usmerjeno mora biti k študentom in osredotočeno na specifične potrebe uporabnikov. Virtualni pacient je posebno orodje za klinični pregled, ki ga lahko učinkovito uporabimo za vaje in ocenjevanje. Sistematični pregledi literature kažejo, da je e-učenje enako učinkovito kot tradicionalne izobraževalne metode, le da lahko nudi drugačne dobrobiti. Članek vključuje analizo prednosti, slabosti, priložnosti in nevarnosti e-poučevanja in e-učenja na področju medicinskega izobraževanja ter izpostavi infrastrukturo, ki je potrebna za podporo e-učenju v okviru medicinskega izobraževanja.

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Introduction

The advancements and innovations of information technology offer a number of modes of delivery of medical information for medical students and physicians in training, and its practical usage in understanding and acquiring medical knowledge and skills. The interactive electronic media are used to facilitate teaching and learning over a range of issues, including health. The term e-learning concerns the engagement of up-to-date internet technologies for transferring knowledge and skills, and for facilitating the teaching of pedagogical skills, learning, consultations, and the possibilities of obtaining varied medical information. Until now, a number of different synonyms have been used when referring to e-learning, such as distance-learning, on-line learning, web-learning, computer-assisted learning and internet-learning. As an educational tool, e-learning should satisfy and maintain the actualities of well-established educational aims by being flexible and enabling good collaboration and communication between students and lecturers. It should be centered towards the specific users' needs but should presumably also be student-oriented.[1-6]

According to the type of transfer when using e-learning applications, e-learning may be web-based or computer-based; according to the type of information delivery, it may be delivered via internet, intranet, extranet, CD-ROM or satellite TV. During the e-learning delivery of medical knowledge the following tools are in use: virtual learning environments (VLE), learning management systems (LMS) and course management systems (CMS). The introduction of a VLE entails innovative, fully-integrated software. A widely known high-quality open source LMS is the Moodle (Modular Object-Oriented Dynamic Learning Environment) system. The main advantage of any e-learning system is the possibility of accessing the learning resources regardless of any time and space constraints. These systems offer continual updating of existing courses and the creating of new ones.[7,8] Several different communicational technologies are presently in use, including the simultaneous involvement of participants at same time, which is the basis of the collaborative learning approach. On-line collaboration can generally be divided into the asynchronous (blogs-personal on-line journals, wiki web-pages, discussion blogs, e-mails), and synchronous (virtual classroom, virtual meetings).[9-12]

E-learning elements and services

The main qualitative elements of any e-learning system are its e-learning content and e-learning processes. The e-learning content may have many forms, such as course materials, articles, lecture notes, presentations, references, protocols, guidebooks and libraries (containing e-books, e-journals and other primary and secondary publications), animations, images, presentations, web-sites, glossaries or key-words. With regard to the structure, e-learning processes may be designed as protocols, schedules or rules. According to the type of protocol, the activities within the e-learning system may be synchronous (e.g., chatting) or asynchronous (e.g., accessing content, taking assessment tests or responding to questionnaires).[9-11] The forums and chat-rooms (formal classes) are specific discussion boards aimed at enabling the asynchronous or synchronous communications of private or open type between participants. Along with textual or schematic materials, multimedia presentations are also in use, as well as online audio or video conferencing (webinars). Every curriculum should be created in such a way as to be easily tracked with regard to the educational process, students' obligations, quality assurance and curriculum mapping. The use of e-learning is well-advanced in many medical schools. The TUSK system (Tufts University Sciences Knowledge-base) and the EEMeC (Edinburgh Electronic Medical Curriculum) system are already widely-used. E-learning is widely employed for medical study throughout the world, including almost the whole of Europe.[9-40]

Experiences with the e-learning system regarding the development of medical courses

Interactive on-line teaching can be employed for different purposes, depending on the context and the needs. It may be used in different forms (textual information, virtual video devices, virtual classrooms), and for different purposes (testing of acquired knowledge, obtaining and checking clinical resilience and experience using virtual patient care) or having insight into healthcare information systems. A system should provide opportunities for the development of different degrees of study, ranging from professional, undergraduate and postgraduate academic levels to continuing medical education, and for different research fields and purposes. Any available infrastructure for supporting e-learning within medical education should have been appropriately established, capable of including accessibility to digital libraries, to internet materials, and to enable technical standardization and methods for the checking of needed resources.[9-12]

Usability of e-learning materials is an essential element for educational impact. There are almost no medical courses that could not be implemented within an e-learning system. The quality depends on the variety of technical options and the availability of modern technical tools, as well as on the digital literacy of both teachers and students. The potential of the e-learning modalities is reflected in a variety of activities and topics capable of facilitating the learning of preclinical, clinical, public health, and research tools for providing a number of instructions and allowing for hands-on practice for treating disorders via highly interactive simulations. These have been evaluated and published over recent years in a number of articles.[1,3,4,12] Focusing on the structures or types of units for delivering the materials, the main elements are lessons, multiple-choice questions, quizzes, discussion groups, or case-studies. Many review or survey articles have recently discussed how the internet is currently being used to provide medical education and addressed some of the devices that should be used to deliver e-learning in an optimal way.[13] However, there are some negative aspects that should also be considered.[14] For example, the use of adaptive e-learning interactive software often encourages the interested users to enter personal data or make choices about providing specific information regarding their living habits and specific disease risks.

Behavioural research has provided evidence that an e-learning system has been able to improve the knowledge and competences of physicians providing medical care within the field of clinical chemistry.[15] Such systems are especially suitable for junior physicians when obtaining clinical proficiencies.[16] Many of the common chronic diseases in children, such as asthma and diabetes type 1, can develop rapidly and may cause serious complications and problems that should be faced by paediatric clinicians. This is especially important for children with special needs who need continual, specific, and complex healthcare requirements throughout their lives because of diseases like epilepsy, cystic fibrosis, developmental and behavioural disorders, cerebral paralysis, spina bifida, attention deficit hyperactivity disorders, mental retardation, autism, traumatic brain injury, or spinal cord injury. Information and healthcare delivery in such cases should be by consultations because the communication between the caregivers and the healthcare providers relates to a wide-range of disease settings. More emphasis should be put on establishing methodological standards such as medical-care guidelines for complex interventions and programs for evaluations.[17,18]

Undergraduate medical teaching regarding occupational health and work-related diseases represents both a need and a challenge and has also been tested as to whether an e-learning system could improve knowledge, satisfaction, and instill a more positive attitude towards occupational health.[19] A survey concerning the use of e-learning in order to enhance medical students' understanding and knowledge of

healthcare-associated infection prevention and control, documented that the majority of students who completed the evaluation were satisfied with this learning experience.[20,21] This strategy in health prevention was designed to provide more flexibility and diversity to the training programmes, as well as an integration of the organizational, teaching, logistical, and budgetary aspects of public health.[21-25] A number of patient-focused internet interactive-based interventions in fertility care have been supported, together with education and promotion about mental-health care.[26]

Virtual morphological disciplines, such as anatomy and pathology at a distance, have gone through substantial advancement over recent years. "Pathology at a distance" was developed not only as an educational tool, but especially for consultations regarding many unresolved pathology cases, whereby experience is exchanged between specialised pathology centres' experts.[5,6,27] The imaging techniques stand out in terms of facing the challenge of how to improve radiologic anatomy knowledge and treatment-planning skills through e-learning. The majority of students who completed the evaluation were positive about the learning experience. The sophisticated medical interventions in radiology were also documented as being effectively provided, such as the case of computed tomographic angiography, where the survey documented that the e-learning program is a useful educational tool that may enhance reading skills and diagnostic confidence in physicians of varying experiences.[28,29] Symbolic machine learning can be successful during image analysis applications.[6] The Virtual Hospital Online represents a new and highly creative learning-support environment. It was developed at the College of Medicine & Veterinary Medicine of the University of Edinburgh.[11,30]

Medical teachers often use animations to illustrate dynamic processes, and simulations to provide opportunities for interactions with clinical problems, such as the simulations for Operating Room or Intensive Cardiology Unit.[31] This has become a need for surgeons in order to acquire new operative skills as a crucial part of surgical competence. A number of techniques, such as e-learning and video-learning, should support the apprenticeship system in order to provide practitioners with highly-structured competencies based on acquired sets of skills. When investigating this new clinical surgery teaching strategy for medical students, more than four thousand individual searches and about 60 participating students provided survey feedback. A significant number found this system highly beneficial and highly relevant. They suggested it should be continued and expanded beyond surgery to other clinical disciplines. This clearly confirms its student-centred structure.[22,32,33] The e-learning education when aimed at improving medical care for patients with specific needs due to chronic psychiatric or neurological diseases has also been documented as being very useful.[34,35]

Computer-assisted learning for nurses within university undergraduate courses also represents an innovative and useful approach. The benefits are reflected in the significantly reduced workloads of the instructors. At the same time, the students receive immediate feedback when offered independent learning and reflective thinking. The online courses are usually designed to socialise students towards the nursing profession, to promote their confidence, to reach their potentials, and to foster their critical thinking abilities, especially in intensive care units and surgical units. This approach is also applicable to any other nursing education institution.[22,33,36,37]

For research-focused education, various e-learning modules relating to cytogenetics, chromosomal aberrations, formal genetics, fundamentals of molecular diagnostics, congenital abnormalities and syndromes have been developed, thus enabling interested student groups with different levels of knowledge or academic researchers to access sophisticated genetic topics.[17,22,23] In addition, a recent survey highlighted the usefulness of e-learning platforms during postgraduate study.[20,26]

Continual medical education (CME) or Continual Professional Development (CPD) are aimed at maintaining up-to-date medical education based on advanced techniques and therapy. Both CME and CPD have found their support in e-learning platforms in order to enhance effective teaching and reinforce the acquisition of specific skills, clinical practice, and clinical attitudes.[12,13]

Virtual patient – a new tool for acquiring clinical experience

Examinations via the e-learning virtual patient testing system tend to impart imperative knowledge for students before entering the hospital system. They virtually interact with the patient, whereby the virtual clinical patient examination enables the enactment of personal responsibility. Some authors have even proposed the usage of simulations as an ethical imperative for accurate and objective medical care because any lack of experience could put patients at risk if being observed by inexperienced young medical doctors.

The virtual patient as a specific clinical examination tool has been explored as a provider of greater efficiency and higher pedagogic value for the training and acquisition of clinical experience, education, and assessment. It represents an example of game-informed learning,[40,41] which was established as practical simulation, capable of simulating complete scenarios during patient observation, from taking anamnesis to clinical-testing (based on the available clinical, laboratory, or image data). The final transition to possible diagnoses proceeds quicker, because of a set of clinical and laboratory data, yielding in this way a proper final therapeutic prescription. It may be created in different forms, such as artificial patients (presumably created based on simulations of human physiology), real patients (based on real electronic health records), physical simulators (mannequins), simulated patients, electronic scenarios or electronic case-studies.[42] Whatever the form, a program can teach clinical skills, bioethics, basic patient communication, history taking, and the final decision-making skills. According to the pedagogical structure, the virtual cases can be created as static or dynamic, or more precisely speaking as linear-passive cases, linear-interactive cases, branching cases, and student-authored cases.[42-45] The static type aims at teaching basic skills for making anamneses and diagnoses. The dynamic type of interactive patient allows students to perform and test advanced clinical skills, from taking history, physical examination, ordering imaging and laboratory tests to the final decision-making and therapy prescriptions. It has been documented that the virtual type of clinical observation may promote and induce essential mental health skills, including critical thinking, communication, and decision-making, with high potential for teaching and learning. It is not only important for the usual practical problems but also for the ability to provide medical care under unusual circumstances.[46,47] The problem-based design or the narrative types are in use, with no differences regarding the main outcomes in communication skills. As these processes may include the designing and constructing of a number of case-scenarios, supported by multimedia components, imaging techniques, laboratory tests and authentic patient management, this would offer multi-professional collaboration when identifying the key abnormalities that play a central role in successful clinical care when making decisions about delicate and difficult-to-resolve situations.[48,49]

The MedBiquitous Curriculum Inventory working group created technological standards for the virtual patient platform in order to promote curriculum reform for healthcare education and assessment. The Harvard Medical School created the Virtual Patient Tutorial Library. It contains an interactive web-based program that uses computer-based patients within simulated clinical encounters involving several diseases' scenarios, such as infective diseases (HIV), chronic diseases (chest pain, cardiovascular diseases, edema, dyspnea and diabetes), altered mental status, pregnancy, dermatological problems, osteoporosis etc. The examinations of virtual patients requiring

clinical skills (neurological, breast, and pelvic examinations) are performed within a virtual Patient-Doctor setup. The virtual patient also provides healthcare professionals with the opportunity to reinforce their training and help, such as interactive virtual simulations of various stroke patients' scenarios in order to assist the management of acute ischemic strokes, as created by Genentech (USA).[46-49]

The most widely used system for virtual patients is probably the MedU (www.med-u.org), developed and provided by the Institute for Innovative Technology in Medical Education, which is a spin-off from the Dartmouth University, New Hampshire, USA. The MedU system contains high-quality and extensive learning contents within the forms of virtual patients in areas of internal medicine, family medicine, paediatrics, surgery and radiology. MedU is presently used in 140 medical schools throughout the USA and Canada.

Our experience

At the Faculty of Medicine in Maribor, we started with the implementation and adoption of the e-learning platform (Moodle) in 2008. Since then we have subsequently developed multimedia learning resources and interactivity elements within our learning programme. In 2008 we started to work on virtual patients and created a test implementation of the Prometheus virtual hospital, as developed by the University of Tübingen, Germany. Today, this system is called the Inmedea Simulator (www.inmedea-simulator.net). Because most of the learning resources were in the German language, whilst our students were mostly fluent in English, we searched for other solutions, and finally opted for the MedU system. We are still in the pilot phase of virtual patient-based teaching and are still exploring how much the North American medical practice and protocols are compatible with the Slovenian ones.

Desirable characteristics of e-learning teachers and lessons

The characteristics of a good teacher for an on-line learning system are not just his/her ability and skills to navigate the computer software. The teacher should know how to properly adapt and create planned time-schedules according to the teaching and/or students' requirements. This means that the students can be offered one of two options: to accept only the more important when they meet the teaching materials for the first time, or whether they want to learn more about the possibilities for upgrading the material by references, links or additional clarifications. This allows the learning to be individualised in a way which is known as adaptive learning, or by enhancing the learners' interactions with other students, which is known as collaborative learning.[12] Thus the two key characteristics of distance learning are creativity and flexibility. The teacher should therefore be competent, prepared and engaged in order to express willingness for communicating with students via e-mails and, in this way, to help them successfully complete the obligatory material of a unit. According to a postulate from one of the founding teachers of e-learning, Gilly Salmon, "the teachers are just as important as ever".

When a teacher decides to submit a text lecture, it should be concise, clear, and contain all the required elements in systematic form.[11] In order to be easier for students or other users to identify what they are really looking for, the names for the courses should be as clear and short as possible. It is also advisable to provide a short summary of the course. This is optional, but very often it can help students make sure that they are looking at the correct course. A course can be divided into a number of sessions, sorted into chronological order or according to scheduled lessons. A course can also contain different materials such as text documents, pictures, or other supporting files. The creator of a course is automatically appointed as that course's tutor. A text should contain any new data that needs to be adapted and adjusted to the

needs of the course and the students. Learning within any medical area is more effective when it is built around relevant publications and support-materials. In addition to the text, there should be simple figures, animations and (possibly 3D) pictures that will help provide better understanding. References, which are a particularly important element of any text, differ between on-line teaching and the classical ex-cathedra teaching. Each reference should have a link that can be easily opened and read. This should be fully reflected from the elementary up to the most advanced and comprehensive contents.

The teacher should also display the characteristics of ethical behaviour and have patience with the persons attending his/her virtual class.[1,3,22,25] The e-moderators should perform the roles of assistants, as already happens during classical teaching. They should take on active discussions with the students that focus on better understanding and acquisition of the anticipated material. They should also foster and adapt the discussions in a flexible way, thus providing equal opportunities for all the active participants to become involved and for the discussions to be directed towards productive outcomes. Discussion, however, is not just questioning or just explanations but rather a successful combination of both. The students should also present good learning performances; they should express willingness and motivation to learn in that way.[9-13]

Two newly-created professional positions arise when introducing an e-learning system, namely the educational technologist and the e-librarian. The educational technologist is responsible for the development, facilitation, and mediation regarding the more suitable educational environments. This means that his/her responsibilities are technical, creative, and administrative. These technical responsibilities require excellent programming skills, whilst highly expressive creative abilities can be expressed through the possibility of translating the language of the words within the educational schemes and animations. The e-librarian should possess technical abilities for searching literature through the internet, and supporting student and teacher access to online resources.[11-13]

A SWOT analysis of e-learning in medical education

Our systematic reviews suggest that e-learning has an effect at least similar to traditional educational methods, but may also offer additional benefits. The first stage of planning and focusing on the key issues of a certain project is a SWOT analysis. The studies and surveys provided at many medical faculties and different courses or study levels around the world have revealed that e-learning is one of the challenges for the future.

Concerning its *strengths*, the e-learning system should be very effective in improving knowledge through standard lecture-based courses because it offers a lot of virtual tools, such as interactive activities, animations, video demonstrations, video clips of experts, and self-assessment exercises.[9,10,40,49] It can be successfully used to improve healthcare practitioners' performances through the usage of simulated clinical practice from enhanced education through the accelerated and well-prepared e-learning modules. Students become proficient at a number of skills that promote success in medical practice. An e-learning system provides a highly-creative approach for forming its own module for any subject. A large number of practical examples may allow the development and improvement of medical thinking and decisions regarding the given problems. This system enables innovation in accordance with the development of information technology, as well as easier and faster access to information. During clinical examination practice, the medical students may not necessarily come into contact with certain entities and rare diseases, which can be compensated for in the virtual environment. The privacy and identity of every patient is of supreme importance, so the simulated virtual situation makes it possible to observe the disease instead of the patient. It is the best way to respect the identities of patients.

As with any new system, e-learning displays certain *weaknesses*. Students often wonder if they did not see something, does it actually exist in real medical practice? Concerning the specific manual skills, a significant difference could be whether the students or healthcare professionals do something personally or can only watch how other professionals work. E-learning within medicine could be argued as being realistic, but not as being real. The lecturer never knows whether he/she has managed to keep the attention of the students. Dependence on information technology means that if it does not function properly, the lecturing becomes impossible. Hence, continual collaboration between pedagogy and technology is required in order for effective e-learning to be delivered during medical studies and medical skills acquisitions.

The *opportunities* lie in the fact that e-learning systems should be flexible in order to be adapted to the students' needs, be innovative, evaluated regularly, and shared amongst faculties. From a commercial point of view, if well designed, an e-learning system may be profitable for an institution that develops and sells it. Students or medical doctors are able attend any e-course unit anywhere in the world from home, thus avoiding the high costs of accommodation.

The *threats* or risks may lie in the fact that those institutions that have large numbers of patients and lower costs of study may be more attractive for students or healthcare professionals than those having to invest into the development of e-learning. At the same time, continual change and progress of information technology quickly render the existing e-learning systems obsolete.

In conclusion, the e-learning technology may support educational processes by offering a lot of creative methodological designs and new pedagogical approaches that are flexible and may provide different types and modes of interaction, cooperation and communication.

References

1. McKimm J, Jollie C and Cantillon P. ABC of Learning and Teaching in Medicine: Web Based Learning. *BMJ* 2003; 326(7394): 870-873.
2. Ellaway R, Masters K. AMEE Guide 32: e-learning in medical education. Part 1: Learning, teaching and assessment. *Med Teach* 2008; 30: 455-473.
3. Sandars, J, Haythornthwaite C. New horizons for e-learning in medical education: ecological and Web 2.0 perspectives. *Med Teach* 2007; 29(4): 307-310.
4. Doherty I and McKimm J. e-Learning in clinical teaching. *Br J Hosp Med* 2009; 71(1): 162-165.
5. Kelc R, Dinevski D. Using Google Body to teach undergraduate anatomy. *Med Educ* 2011; 45(11): 1155-1156.
6. Zorman M, Sánchez de la Rosa JL, Dinevski D. Classification of follicular lymphoma images: a holistic approach with symbol-based machine learning methods. *Wien Klin Wochenschr* 2011; 123(23-24): 700-709.
7. Nunez JC, Cerezo R, Bernardo A, Rosario P, Valle A, Fernandez E, Suarez N. Implementation of training programs in self-regulated learning strategies in Moodle format: results of an experience in higher education. *Psicothema* 2011; 23(2): 274-281.
8. Seluakumaran K, Jusof FF, Ismail R, Husain R. Integrating an open-source course management system (Moodle) into the teaching of a first-year medical physiology course: a case study. *Adv Physiol Educ* 2011; 35(4):369-377.
9. Ellaway R. Weaving the 'e's together. *Med Teach* 2006; 28(7):587-590.
10. Masters K, Ellaway R. AMEE Guide 32: e-Learning in medical education. Part 2: Technology, management and design. *Med Teach* 2008; 30(5): 474-489.
11. Salmon G. E-moderating: *The key to online teaching and learning* (3rd ed.). London 2011: Routlege;.
12. Ruiz JG, Mintzer MJ, Leipzig RM. The impact of e-learning in medical education. *Acad Med* 2006; 81(3): 207-212.
13. Sinclair P, Schoch M, Black K, Woods M. Proof of concept: developing a peer reviewed, evidence-based, interactive e-learning programme. *J Ren Care* 2011; 37(2): 108-113.
14. Sharma N. The negatives of e-learning. *Clin Teach* 2011; 8(2): 142-143.
15. Rizos D, Karababa P, Sarandakou A *et al*. Greek National Clinical Chemistry Registration

Commission. The organization of an educational program for specialists in clinical chemistry by the Greek Society of Clinical Chemistry-Clinical Biochemistry. *Biochem Med* 2011; 21(1): 30-37.
16. Gordon M, Chandratilake M, Baker P. Improved junior paediatric prescribing skills after a short e-learning intervention: a randomised controlled trial. *Arch Dis Child* 2011; 96(12): 1191-1194.
17. O'Leary FM, Janson P. Can e-learning improve medical students' knowledge and competence in paediatric cardiopulmonary resuscitation? A prospective before and after study. *Emerg Med Australas* 2010; 22(4): 324-329.
18. Gill P, Kitney L, Kozan D, Lewis M. Online learning in paediatrics: a student-led web-based learning modality. *Clin Teach* 2010; 7(1): 53-57.
19. Baillargeon M, Maheux B, Gilbert A. The challenge of teaching occupational medicine to medical students: the Université de Montréal experience. *J Occup Environ Med* 2011; 53(11): 1258-1261.
20. Muñoz DC, Ortiz A, González C, López DM, Blobel B. Effective e-learning for health professional and medical students: the experience with SIAS-Intelligent Tutoring System. Stud Health Technol Inform 2010; 156: 89-102.
21. Sandars J. The e-learning site. *Educ Prim Care* 2010; 21(3): 206-207.
22. Papachristodoulou D. Learning experiences and assessment in the first 2 years of the medical course at King's College London School of Medicine. *Keio J Med* 2010; 59(4): 140-145.
23. Myrick F, Caplan W, Smitten J, Rusk K. Preceptor/mentor education: a world of possibilities through e-learning technology. *Nurse Educ Today* 2011; 31(3): 263-267.
24. O'Neill E, Stevens NT, Clarke E, Cox P, O'Malley B, Humphreys H. Use of e-learning to enhance medical students' understanding and knowledge of healthcare-associated infection prevention and control. *J Hosp Infect* 2011; 79(4): 368-370.
25. Solomon P, Baptiste S, Hall P, Luke R, Orchard C, Rukholm E, Carter L, King S, Damiani-Taraba G. Students' perceptions of interprofessional learning through facilitated online learning modules. *Med Teach* 2010; 32(9): e391-e398.
26. Ehlers J, Behr M, Bollwein H, Beyerbach M, Waberski D. Standardization of computer-assisted semen analysis using an e-learning application. *Theriogenology* 2011; 76(3): 448-454.
27. Giansanti D, Grigioni M, D'Avenio G, *et al*. Virtual microscopy and digital cytology: state of the art. *Ann Ist Super Sanita*. 2010; 46(2): 115-122.
28. Njuguna N, Flanders AE, Kahn CE Jr. Informatics in radiology: envisioning the future of e-learning in radiology: an introduction to SCORM. *Radiographics* 2011; 31(4): 1173-1179.
29. Carriero A, Beomonte Zobel B, Bonomo L, *et al*. E-learning in radiology: Italian multicentre experience. *Radiol Med* 2011; 116(7): 989-999.
30. Paul Rosen P, Gentles SJ, Lokker C, McKibbon A. Health information technology to facilitate communication involving health care providers, caregivers, and pediatric patients: a scoping review. *J Med Internet Res* 2010; 12(2): e22.
31. Hickey KT, Johnson MP, Biviano A, *et al*. Cardiac e-learning: development of a web-based implantable cardioverter defibrillator educational system. *Telemed J E Health* 2011; 17(3): 196-200.
32. Jakimowicz JJ, Jakimowicz CM. Simulation in surgery. Where are we now and where to from here? *Cir Cir* 2011; 79(1): 41-45.
33. Fernández Alemán JL, Carrillo de Gea JM, Rodríguez Mondéjar JJ. Effects of competitive computer-assisted learning versus conventional teaching methods on the acquisition and retention of knowledge in medical surgical nursing students. *Nurse Educ Today* 2011; 31(8): 866-871.
34. Beijer LJ, Rietveld TC, Hoskam V, Geurts AC, de Swart BJ. Evaluating the feasibility and the potential efficacy of e-learning-based speech therapy (EST) as a web application for speech training in dysarthric patients with Parkinson's disease: a case study. *Telemed J E Health* 2010; 16(6): 732-738.
35. Ruiz JG, Tunuguntla R, Cifuentes P, Andrade AD, Ouslander JG, Roos BA. Development and pilot testing of a self-management internet-based program for older adults with overactive bladder. *Urology* 2011; 78(1): 48-53.
36. Wahl SE, Latayan MB. Nursing education innovation: using e-learning technology to meet learners' needs. *J Contin Educ Nurs* 2011; 42(11): 483-484.
37. Carruth AK, Broussard PC, Waldmeier VP, Gauthier DM, Mixon G. Graduate nursing online orientation course: transitioning for success. *J Nurs Educ* 2010; 49(12): 687-690.
38. Bergin, RA, Fors, UGH. Interactive simulated patient – an advanced tool for student-activated learning in medicine and healthcare. *Comput Educ* 2003; 40: 361-376.

39. Bergin R, Youngblood P, Ayers MK, *et al*. Interactive simulated patient: experiences with collaborative e-learning in medicine. *J Edu Comp Res* 2003; 29(3): 387-400.
40. Poulton T, Balasubramaniam C. Virtual patients: a year of change. *Med Teach* 2011; 33(11): 933-937.
41. Ellaway R, Evans P, McKillop J, *et al*. Cross-referencing the Scotish Doctor and Tommorow Doctors learning outcome frameworks. *Med Teach* 2007; 29(7): 630-635.
42. Ortega Lde M, Plata RB, Jiménez Rodríguez ML, *et al*. Using M-learning on nursing courses to improve learning. *Comput Inform Nurs* 2011; 29(6 Suppl): TC98-104.
43. Khogali SE, Davies DA, Donnan PT, *et al*. Integration of e-learning resources into a medical school curriculum. *Med Teach* 2011; 33(4): 311-318.
44. Huang G, Reynolds R, Candler C. Virtual patient simulation at US and Canadian medical schools. *Acad Med* 2007; 82: 446-451.
45. Ellaway R, Poulton T, Fors U, McGee JB, Albright S. Building a virtual patient commons. *Med Teacher* 2008; 30: 170-174.
46. Triola M, Feldman H, Kalet AL, *et al*. A randomized trial of teaching clinical skills using virtual and live standardized patients. *J Gen Intern* Med 2006; 21: 424-429.
47. Sijstermans R, Jaspers MWM., Bloemendaal PM, Schoonderwaldt EM. Training inter-physician communication using the dynamic patient simulator. *Int J Med Inform* 2007; 76: 336-343.
48. Bearman M, Cesnik B, Liddell M. Random comparison of "virtual patient" models in the context of teaching clinical communication skills. *Med Educ* 2001; 35: 824-832.
49. Saleh N. The value of virtual patients in medical education. *Ann Behav Sci Med Educat* 2010; 16(2): 29-31.