2011; 33: 279–285 MEDICAL TEACHER

HOW WE. . .

How we develop and sustain innovation in medical education technology: Keys to success

JAMES B. MCGEE & STEVEN L. KANTER
University of Pittsburgh School of Medicine, USA

Abstract

The use of information technology to support the educational mission of academic medical centers is nearly universal; however, the scope and methods employed vary greatly (Souza et al. 2008). This article reviews the methods, processes, and specific techniques needed to conceive, develop, implement, and assess technology-based educational programs across healthcare disciplines. We discuss the core concepts, structure, and techniques that enable growth, productivity, and sustainability within an academic setting. Herein are specific keys to success with examples including project selection, theory-based design, the technology development process, implementation, and evaluation that can lead to broad participation and positive learning outcomes. Most importantly, this article shares methods to involve students, faculty, and stakeholders in technology design and the development process that fosters a sustainable culture of educational innovation.

Introduction

Essentially, all North American medical schools use information technology (IT) to support their educational mission with a combination of web-based curricular materials, course management, virtual patients, patient logs, online evaluations, and other software applications (Kamin et al. 2006). However, the scope of activities and implementation methods vary greatly from school to school, as do the organizational and administrative mechanisms supporting these services (Souza et al. 2008). Little is published about how best to deliver and support medical education technology.

This article reviews the core concepts, structure, and techniques for success in education technology in an academic environment. To illustrate, we use the Laboratory for Educational Technology at the School of Medicine at the University of Pittsburgh as an example. The Lab's mission is to enhance medical education through the discovery, development, and validation of new learning technologies – not only to solve educational problems but also to seek opportunities to use technology to enhance learning beyond traditional approaches. Here we share the methods our Lab and others use to conceive, develop, implement, and assess a range of large-scale software applications and technology programs for learning. In an effort to guide other developers and users of education technology, we detail here the key success factors, provide examples, and share lessons learned that led to a culture of technology innovation at our institution.

Practice points

- A school of medicine-based education technology laboratory can foster a culture of innovation in teaching and learning.
- Careful selection of projects, modern software production techniques, and diverse sources of funding are necessary to sustain a school of medicine-based education technology laboratory.
- Academic technology groups should focus on developing and supporting flexible technologies that can be applied across all levels of training and disciplines.
- Involvement of students and faculty throughout the design and implementation of new learning technologies.

Getting started

In 2001, as the use of web-based technology was emerging in medical education, the University of Pittsburgh School of Medicine established the Laboratory for Educational Technology. This research and development lab's mission was not only to discover and build educational software but also to ensure widespread adoption of online interactive techniques among faculty and students. The Lab reported directly to the vice dean who is responsible for the school's educational programs, faculty affairs, student affairs, financial aid, and admissions, and worked closely with the Office for Medical Education and the Curriculum Committee. The primary focus was on the needs of the 4-year medical curriculum but with some autonomy to work with clinical trainees and continuing professional education and on externally funded projects.

This was a similar approach taken by Harvard's education technology group and Stanford's SUMMIT where and

Correspondence: J. B. McGee, Department of Internal Medicine, Division of Gastroenterology, Hepatology and Nutrition, University of Pittsburgh School of Medicine, 3550 Terrace Street, Room M256 Mezzanine Level, Scaife Hall, Pittsburgh, PA 15213, USA. Tel: 1 412 6489679; fax: 1 412 6489378; email: mcgee@medschool.pitt.edu

ISSN 0142–159X print/ISSN 1466–187X online/11/040279–7 © 2011 Informa UK Ltd.
DOI: 10.3109/0142159X.2011.540264

educational IT center served the direct needs of the medical school and could still pursue experiments and research with novel technologies. Other schools chose to use IT resources based at either the academic medical center or provided by the university (Souza et al. 2008). Each model has its advantages and disadvantages relating primarily to flexibility, independence, and sustainability. An education IT group based at the medical school and funded by external sources (grants, contracts, and philanthropy) can typically select its own priorities and pursue riskier projects than one that is supported by the University or Academic Medical Center.

As demand for web-based learning tools grew, the Lab in Pittsburgh evolved to a team of nine education and technical specialists along with its portfolio of offerings including,

- integrated web portal with single-sign-on role-specific access to all educational, administrative, and extracurricular online systems
- collaborative online learning environments for project and team activities
- clinical experience logs for tracking of patient encounters and procedures
- just-in-time learning, providing on-demand contextual modules triggered by clinical encounters
- virtual patient simulation – interactive computer-based simulations of clinical cases

Core concepts

Four concepts related to educational software development guided the Lab's early work:

- build technology tools that scale vertically and horizontally across disciplines and learners;
- put easy-to-use online content development tools in the hands of educators;
- provide easy access to educational design and support personnel; and
- maintain a relationship with the faculty and students that encourages pursuit of new ideas.

This combination of flexible, easy-to-use software tools and an open-door policy that encouraged and supported faculty and student ideas led to a culture of innovation.

Funding

The seed funding for the Laboratory for Educational Technology came from the School of Medicine discretionary funds and represented an uncommon investment at the time. As the Lab evolved, it continued to derive core support from the school but grew in scope and depth through external funding using a mix of federal grants, foundation support, unrestricted educational grants from industry, and cost-recovery from clinical departments. This approach worked well since it allowed the Lab flexibility in selecting projects, the ability to grow in scope, and at the same time avoided participation in programs that did not support themselves financially.

These early decisions regarding structure and funding proved critical to the success and sustainability of our education technology initiatives during a period when legitimate skepticism regarding the role of technology was common. The most important decision continues to be the inclusion of students and faculty in the technology development process.

The remainder of this article examines the specific success factors found most valuable accompanied by specific examples from our own educational technology lab. We believe that these success factors and the lessons we learned will be valuable to other schools in their own technology decision-making and development efforts to solve educational challenges, offer new opportunities for learning, and stimulate innovation.

Key success factors

The ability to fund and sustain an education technology program and to design, develop, implement, and assess its many software projects and programs, in our experience, is dependent on a number of key success factors.

Key success factors – Selection of projects

New educational technology projects tend to begin when either a specific educational need arises or as a novel idea from faculty, administration, or students. Because the number of opportunities usually exceeds available resources, one must assess and select only the new ideas that have the most potential, while at the same time not discouraging innovation and experimentation.

Key 1: Assess the educational need and value to the stakeholders. When a new idea or an educational need is identified, take time to assess its value to the learning process and institutional educational goals. This step extends from needs assessment to assessment of the short- and long-term educational impact of the proposed technology.

While needs assessment is a well-recognized initial step (Kern et al. 1998), we at the same time are careful to include all stakeholders (administration, students, and faculty) and document their perspective regarding the project's potential impact. Also, we perform an investigation into existing solutions and ask other institutions what worked, what did not work, the reason for success/failure and, most importantly, and what they would do differently the next time. This due diligence can save time and money (Cook & Dupas 2004). Objective analysis of all stakeholders' needs not only facilitates project selection but their early participation proves valuable during later stages of design, development, and implementation.

Questions to ask stakeholders:

(1) Does the new idea reflect a true opportunity to (a) solve an educational problem, (b) improve an existing program, or (c) learn/teach in a new and better way?
(2) Will this technology make learning better and not just different?

(3) How generalizable is the problem and the proposed solution? Will learners in other disciplines, levels of training, and other institutions benefit?

Key 2: Assess the technical feasibility. Following needs assessment, we engage in a technical consultation with our own staff and external experts. The Lab uses its own experience, technical analysis, and a global network of education technologists to answer critical early questions. Reaching outside one's own institution was valuable since many educational projects, especially the unsuccessful ones, are never reported in the academic literature. Awareness of other school's experience as reported at regional, national, and international conferences along with personal communication adds significantly to initial project assessment (Cook 2006).

Questions for internal education and technical staff:

(1) Is the project within our capabilities and resources? Does it build on existing areas of expertise and in-house skills?
(2) What is the likelihood that the proposed technology can solve the problem?
(3) Can the identified problem be best-addressed using existing technology or a traditional method?
(4) What are the perceived technical and implementation limitations?

Questions for external consultants:

(1) Has a similar idea already been tried before locally or elsewhere?
(2) What worked, what did not work, and where were the barriers?
(3) How would they do things differently the next time?

Key 3: Estimate the costs and benefits. Cost is generally underestimated when educational projects are developed within an academic environment. Some may only tally the new direct costs such as software, computer hardware, and additional staff. Large indirect costs such as the time spent by existing faculty and staff who are therefore unavailable for other teaching activities are often overlooked. Totaling the true costs is necessary to adequately weigh against the benefits. The cost of sustaining a new program is another often overlooked item. This includes faculty time required to keep the educational content current, the staff time to handle support, and the technical resources needed to update the software to work with evolving computer hardware, operating systems, and web browsers.

Analyzing the risks and benefits of a project, monetary, and otherwise, is key in the selection and prioritization process.

Questions to estimate cost:

(1) What are the true total costs for design and development – both out-of-pocket expenses and in-kind contributions?
(2) How much faculty and staff time is required to develop and implement a new program?
(3) How much staff time and annual expenses are necessary to sustain the project?
(4) Is there adequate funding and faculty interest to sustain the long-term content development of a program?
(5) What is the cost of failure?

Despite initial optimism usually associated with a new project, someone has to ask the question "what if it doesn't work?" Timelines and milestones should be examined carefully and alternatives identified if critical deliverables and expectations are not achieved.

At the University of Pittsburgh, we employ an agile-development approach; identifying and working on the highest-risk components of a project first, then repeatedly testing functions and features with end-users before continuing on. This allows for early identification of problems and adjustments to design well before critical deployment dates.

Questions to estimate benefit:

(1) How big of a problem does the proposed technology solve?
(2) How many learners and educators are impacted by this new technology?
(3) Will this new program scale horizontally to include other topics, and vertically to new and larger audiences?
(4) Does this project have the potential to contribute to medical education outside the institution?

In our experience and others, investing in learning technologies is more beneficial as the audience size grows and the separation of teachers from students (by space and time) increases (Taradi et al. 2008). A new project has far more value if it can be used for a variety topics and disciplines (Cook & Dupas 2004) and by different audiences such as residency trainees, allied health, and continuing education. Finally, we try to determine a proposed technology's novelty and its potential to add new learning techniques to medical education in general.

> EXAMPLE: Web-based virtual patients are an example of a technology used widely to teach many subjects, in a variety of settings and across the spectrum of medical education. In Pittsburgh, we use virtual patients in small group-learning rooms where students take turns interviewing, examining, ordering diagnostic tests, establishing a differential diagnosis, and instituting therapy. Adding technology to problem-based learning enhances exploratory learning and facilitates the use of high-resolution images, audio, video, and web-based resources in a way that stimulates group discussion (Kerfoot et al. 2005). Researchers at the Karolinska Institute have taken the web-based case discussion further by using live online chat between PBL groups at Stanford in California, USA, and Stockholm, Sweden (Zary et al. 2006). This same web-based virtual patient software is used in many disciplines and adapted for a variety of audiences from classroom teaching to independent continuing education.

Key 4: Avoid single-purpose educational programs. Faculty occasionally approach the Lab with proposals for web-based learning programs targeted at a single, specific educational need for a single audience. Typically, after working with our educational designers, the same objectives can be met by entering their new content into an existing system. On the contrary, when an educator proposes a unique learning tool with broad applicability, the Lab encourages and supports the development of their new program.

> EXAMPLE: A motivated faculty member sought to create a web site for obstetrics education targeted to Internal Medicine residents. Instead of creating a custom one-off application, she worked with the Lab's educational designers to adapt the existing General Medicine Online Modules software (a derivative of the Navigator Learning management System (LMS)) to interactively deliver her educational content. New features were added for research purposes to confirm the effectiveness of this approach (Spagnoletti et al. 2007).
>
> EXAMPLE: The Lab collaborated with the Palliative Care faculty to conceive a novel approach to teaching end-of-life clinical skills to clinical clerkship students. A "Just-in-Time" learning system was devised where students' existing clinical patient logs trigger on-demand learning modules tailored to the diagnoses entered into the log. Normally, single-topic subject matter would not warrant a large-scale development project, but we recognized that this unique approach could be applied to any discipline, not just palliative care.

Key success factors – Design and development

The following are concepts and techniques that we found helpful during the design and development phase of a new project, especially when working in an academic environment. While a comprehensive review of software design and development is beyond the scope of this article, these are the most important factors that helped our educators and developers reach their goals.

Key 5: Define the project's audience, environment, and motivational factors. At the beginning of a new project, clearly document a project's scope and learners' motivational factors to aide design decisions throughout development.

(1) Who is the audience?
(2) What is the setting your technology will be used in?
(3) What will motivate the learner to engage with your program?

The audience for education software is not just the student. It also includes the content expert(s), supporting faculty, administrative staff, and others. For example, will educators use your software to create new learning content independently or include the help of an instructional designer? Also, will course directors or administration need reports reflecting completion and student performance?

Defining the setting, whether it is in a classroom, a small group, or for independent learning, greatly affects software design and implementation plans. A web exercise that is intended for facilitated small group learning should be experiential and trigger additional deeper learning external to the exercise itself. However, if a program is intended for independent learning, the necessary educational content should be embedded and adapted for a variety of learners since there is no facilitator or teacher present to fill in knowledge gaps and guide learning.

Finally, what will motivate the intended learner to seek out and engage with your program? Will this be part of required curricular material or optional self-motivated learning? Is completion mandatory? Will a specific performance level be required for a passing grade? Are there consequences for *not* satisfactorily completing the program?

In our experience, beginning the design and development process prior to specifying an audience, environment, and motivation, can be problematic and require redesign and rewriting software to meet previously unrecognized requirements.

Key 6: Successful technology development follows good educational design. Designing an effective educational software application or new technology is similar to designing any successful educational program and employs similar principles and skills. Success requires the combined knowledge and skills of instructional designers, software technicians, content experts, educators, and learners (Lang 2005). At the Lab, the development process begins by critically examining a course or program's overall current educational design. This includes defining learning goals, workflow, and desired outcomes. The time and effort expended at this stage forces new courses and educational programs to critically evaluate their overall educational design, before software design begins.

Questions for the educational design team:

(1) What are the desired educational outcomes, such as new knowledge, skills, and changes in behavior or attitudes?
(2) What learning does this program replace or enhance?
(3) Where in a learner's educational workflow does the program fit?
(4) How will the learner know the necessary steps have been completed at the required level of proficiency?
(5) How will the learning outcomes be measured?

> EXAMPLE: Our medical student Scholarly Project, a longitudinal project-based learning experience needed a mechanism for students and their mentors to communicate, share documents, and submit reports. Before designing a supporting technology, the Lab's instructional designers and technical staff carefully reviewed and documented the Scholarly Project's educational goals. They analyzed the students' and mentors' workflow and designed a solution that fit both the users' needs and achieved the program's educational goals. This collaborative development process between the software design team and the program stakeholders ensured good educational design before writing the first line of

software code and contributed to the success of the program (Boninger et al. 2010).

Key 7: Employ adult learning theory where appropriate. Attention to relevant learning theories during the software design process leads to more effective outcomes and learner acceptance (Ruiz et al. 2006). Instructional designers in our lab lay out a roadmap built on sound learning theory that guides the software design process. We ask collaborating experts and ourselves questions regarding how well a proposed software design relates to adult learning theory.

Questions for the educational design team:

(1) What cognitive level(s), using Bloom's taxonomy, are we trying to achieve?
(2) How self-initiated and self-directed is the design?
(3) What is the balance of active versus passive learning?
(4) Can we relate the lesson to a clinical experience?
(5) Can the learner engage in problem solving?
(6) Can feedback be individualized based on the learner's prior knowledge and performance?

EXAMPLE: Working with educators, the Lab applied self-directed and contextualized learning theories to the design of its Just-in-Time learning system. This educational tool provides students with brief online learning modules based on their daily electronic patient log entries. The learning is self-initiated and relates to an actual clinical case at a time when new knowledge may be applied and outcome to the problem observed.

Key 8: Well-designed educational software can be used in multiple learning settings. We focus our efforts on developing learning "tools" that can be used with a range of topics and for learners at different levels of education and training. The Lab tries to design technology projects to be content agnostic so they might apply vertically from novice to expert *and* horizontally across disciplines.

EXAMPLE: The Lab's Navigator LMS was originally designed for the undergraduate medical school curriculum. Today, Navigator has 12 distinct variations serving medical students, residents, dental students, and continuing education. Each group manages its own digital content, access control, educational features, functionality, and user interface. However, all 12 versions use the same software code, database, and network services.

EXAMPLE: Developing our own blog (web-log) application proved valuable despite the availability of commercial and open-source blog software. Initially, course directors used their individual blogs to post daily updates about the course and field questions from students. Later, students used a slightly modified version of the course blog to discuss project progress with their Scholarly Project mentors. Students use yet another version of the blog software to discuss their PBL cases with small group members. By developing our own technology, we were able to customize and integrate it smoothly with our own LMS and portal applications.

Key 9: Commercial software, when carefully selected, can be the best solution. The Lab's mission is to encourage innovation and creativity and, as a result, most of our software solutions are developed in-house. However, using commercial applications, especially when they can be customized to local needs, can be less expensive and shorten the time to implementation.

EXAMPLE: The medical students needed a web portal in just 4 months, eliminating the possibility of building one from scratch. SharePoint™ (Microsoft, Redmond, CA), a business-oriented portal and collaboration software platform, was selected because of its "out-of-the box" capabilities. Just as important, its features could be extended using software plug-ins called "web parts." We were able to deliver the basic portal functionality on time and later extend its value by writing our own medical education-specific web parts.

Key success factors – Implementation and assessment

Key 10: Employ a stable, fast, and scalable IT infrastructure. Students have come to depend on their online educational resources and software daily and at all hours. They have a low tolerance for downtime and slow performance. Usability research tells us that latency, the time between when a user requests information and receives a response, significantly affects perception of the value of the data returned (Borella et al. 1997). To insure reliable performance, we outsource our IT network and server services to another department's large dedicated network services group. This allows the development team to focus on the software application development and direct support of students and faculty. Modern dedicated "data centers" can provide flexibility and security beyond what most medical schools could reasonably equip themselves. They can quickly expand storage, speed, and bandwidth to adjust to changing needs and their backup, failover, and recovery capabilities are typically superior. Some schools are now experimenting with large commercial services such as Google (Mountain View, CA) and Amazon (Seattle, WA) who offer attractive prices if your IT needs are large.

Key 11: Encourage faculty participation by providing software tools and teaching them how to creatively use them. Teaching faculty are generally highly motivated educators and when given the opportunity, they find creative ways to educate their students. When taught how to use flexible educational tools, we found that faculty members independently adapted them to their individual teaching needs, some times in ways we did not predict. To this end, the Lab's education specialists make themselves highly available and schedule regular one-on-one meetings to introduce them to new technologies. Faculty development, when conducted properly, is essential for success and sustainability of educational technology. For example, we sought out and hired an educational designer with a degree focused on faculty adoption of technology. He proved critical to the school's ability to distribute technology broadly and deeply throughout the curriculum.

Key 12: Embed stakeholders in program assessment. Evaluation must not be an ''afterthought'' but rather an integral part of every development program. Early in the conception and throughout the formative evaluation phase of a new technology, the stakeholders (students, faculty, and administration) participate in the design and validation of features and functionality. Additionally, a variety of formative and summative evaluation methods are used to obtain user feedback at all stages of project development and following implementation. Methods employed included but are not limited to user interviews, formal usability testing, focus groups, and surveys. We are careful to include a mix of students and faculty at all stages. We found that because students and faculty are a demanding and vocal audience, subjective evaluation techniques were well suited to our environment. They never hesitated to share candid opinions and suggestions.

> EXAMPLE: The design of a new user interface for the students' patient log application benefitted from ''think-aloud'' formative assessment methods (von Mayrhauser & Vans 1995) where six students individually described their thoughts while interacting with early versions of the new application. A silent observer notes when and where the students have problems. The software designers and programmers use these transcripts to make mid-stream adjustments to the software.

Discussion and conclusions

In this article, we describe approaches to the organization, support, and process of delivering innovative technology for learning. Others have described the organizational structures used to support education technology at medical schools (Souza et al. 2008) and methods for effective educational software development (Candler 2007; Ellaway & Masters 2008). Here, we go further by sharing the structural and methodological keys that led others and us to successful technology programs and positive educational outcomes. As a result, at the University of Pittsburgh School of Medicine, students and faculty now regularly communicate asynchronously via Blogs, conduct projects on dedicated collaborative learning websites, track clinical experiences, and receive contextual learning from online patient logs. We developed these programs collaboratively with faculty and students and tailored them to the specific educational needs of our learners.

While there is a paucity of objective evidence showing that technology, as an independent variable, positively impacts medical education (Cook 2006), faculty and student adoption can be reasonable indicators of value. Our LMS is voluntarily used by every course director and receives 3.6 million page views by our 150 students every year. Students and faculty together created over 2500 collaborative learning websites where they view 5.6 million pages annually. Even a focused application such as the student patient log receives 234,000 page views a year. Another half-million pages are viewed every year on the dozens of smaller LMS sites for dental, residency training, and continuing education. Numbers are not the only impact factor; some technologies that allow learning in new ways have value beyond just utilization. For example, educating using virtual patient simulation and just-in-time learning would not be possible without computer technology. Discovery and development of these and future innovative approaches to learning require dedicated resources and personnel such as our education technology laboratory. Our experience has shown us that relying on just off-the-shelf commercial software is not enough to meet the needs of our learners and faculty.

Students entering medical school now have grown up using the Internet for both learning and social activity. This generation of learners possesses advanced skills and unique expectations for technology in all parts of their lives (McGee & Begg 2008). With this comes an increasing need for continuous evolution in medical education technology and related faculty development.

When properly implemented, education technology centers bring more than just software to the learning experience. They provide an outlet for purposeful experimentation of new education ideas. They not only provide just technical expertise but also much needed educational design and project management for new curricular initiatives. Ultimately, we feel that education technology fosters a culture of educational innovation where new ideas and initiatives are acted on and sustained.

Acknowledgments

The authors would like to thank Charles P. Friedman, PhD, for his inspiration and guidance that led to the formation of the Laboratory for Educational Technology.

Declaration of interest: Dr. McGee is the Chair of the Scientific Advisory Board and equity holder in Decision Simulation LLC. Dr. Kanter has no declarations of interest to claim.

Notes on contributors

JAMES B. MCGEE, MD, is an Associate Professor of Medicine, Assistant Dean for Medical Education Technology, and Director of the Laboratory for Educational Technology at the University of Pittsburgh School of Medicine.

STEVEN L. KANTER, MD, is the Vice Dean of the University of Pittsburgh School of Medicine.

References

Boninger ML, Schor N, Humphrey A, McGee JB, Kant P, Willochel M, Kanter SM. 2010. Implementation of a longitudinal mentored scholarly project: An approach at two medical schools. Acad Med 85:429–437.

Borella MS, Sears A, Jacko JA. 1997. The effects of Internet latency on user perception of information content. Phoenix AZ, USA: Proceedings of Global Telecommunications Conference Vol. 3. pp 1932–1936.

Candler C. 2007. Effective use of educational technology in medical education. Washington DC, USA: Presented at the Colloquium on Educational Technology: Recommendations and Guidelines for Medical Educators. AAMC Institute for Improving Medical Education.

Cook DA. 2006. Where are we with web-based learning in medical education? Med Teach 28:594–598.

Cook DA, Dupas DM. 2004. A practical guide to developing effective web-based learning. J Gen Intern Med 19:698–707.

Ellaway R, Masters K. 2008. AMEE Guide 32: e-Learning in medical education. Part 1: Learning teaching and assessment. Med Teach 30:455–473.

Kamin C, Souza KH, Heestand D, Moses A, O'Sullivan P. 2006. Educational technology infrastructure and services in North American medical schools. Acad Med 81:632–637.

Kerfoot BP, Masser BA, Hafler JP. 2005. Influence of new educational technology on problem-based learning at Harvard Medical School. Med Educ 39:380–387.

Kern D, Thomas P, Howard D, Bass E. 1998. Curriculum development for medical education. Baltimore. MD: Johns Hopkins University Press.

Lang M. 2005. Are instructional designers software architects in disguise? IT Forum. [Published 2008 October 25]. Available from: http://it.coe.uga.edu/itforum/paper82/paper82.html

McGee JB, Begg M. 2008. What medical educators need to know about Web 2.0. Med Teach 30:164–169.

Ruiz JG, MIntzer MJ, Leipzig RM. 2006. The impact of e-learning in medical education. Acad Med 81:207–212.

Souza KH, Kamin C, O'Sullivan P, Moses A, Heestand D. 2008. Organizational models of educational technology in US and Canadian medical schools. Acad Med 83:691–699.

Spagnoletti CL, Sanders AM, McGee JB, Bost JE, McNeil MA. 2007. Teaching obstetric medicine to Internal medicine residents: An effective web-based approach. Teach Learn Med 19:393–396.

Taradi SK, Đogaš Z, Dabić M, Drenjančević PI. 2008. Scaling-up undergraduate medical education: Enabling virtual mobility by online elective courses. Croat Med J 49:344–351.

von Mayrhauser A, Vans AM. 1995. Program understanding: Models and experiments. In: Yovita MC, Zelkowitz MV, editors. Advances in computers., Vol. 40. New York: Academic Press. pp 1–38.

Zary N, Johnson G, Boberg J, Fors UG. 2006. Development, implementation and pilot evaluation of a web-based virtual patient case simulation environment – Web-SP. BMC Med Educ 6:10.