3 Neuberger J. *Review of the Liverpool Care Pathway for Dying Patients*. London: Department of Health 2013.
4 Anonymous. After Mid Staffs: the NHS must do more to care for the health of its staff. *BMJ* 2013;**346**: 1503.
5 Regehr G. It's NOT rocket science: rethinking our metaphors for research in health professions education. *Med Educ* 2010;**44**:31–9.
6 Stokes D. *Pasteur's Quadrant: Basic Science and Technological Innovation*. Washington, DC: Brookings Institution Press 1997.
7 Reason J. Beyond the organisational accident: the need for 'error wisdom' on the frontline. *Qual Saf Health Care* 2004;**13** (Suppl 2):28–33.
8 Merton RK. The unanticipated consequences of purposive social action. *Am Sociol Rev* 1936;**1** (894): 904.
9 Stacey RD. *Strategic Management and Organisational Dynamics: The Challenge of Complexity to Ways of Thinking about Organisations*. Upper Saddle River, NJ: Pearson Education 2007.

The challenge of disruptive innovation in learning technology

James Bateman & David Davies

We know that computer-based instruction works.[1] The question that remains to be resolved concerns what the most effective form of computer-based instruction might be. Are there consistent design attributes that will ensure the achievement of educational outcomes, and are there applications of learning theory that can be used to guide the design of effective computer-based instruction? The paper by Lau[2] in this edition of the journal reviews a number of studies to derive a useful list of design principles to help guide the development of computer-based instruction modules. Readers may also wish to consult another list produced by Mayer and published in an earlier volume of this journal.[3] The distinction between what constitutes computer-based teaching modules (CBTMs), as defined by Lau,[2] and other forms of computer-based instruction is not as clear-cut. There is nothing inherent in multimedia learning, computer-based learning, Internet-based learning or related approaches that make them part of a blended learning approach, except that which the teacher has designed. Therefore, it could be argued that Lau's[2] CBTM is not a unique learning approach. However, we do welcome an evidence-based list of design principles, especially if it helps us to design more effective learning opportunities.

Are there consistent design attributes that will ensure the achievement of educational outcomes?

Lau[2] describes the CBTM as a distinct approach, but this must be seen in the context of continued developments in web-based learning. New approaches in education, such as massive online open courses (MOOCs), have considerable overlap with the CBTM and have the potential to demolish the rule book on how we approach educational interventions.[4] MOOCs are wildly popular: course enrolments in the tens of thousands are common. They also benefit from considerable investment,[5] yet they are so new that there is little or no evidence for how educationally useful they are, or how they might be financially sustained. This presents obvious challenges as to how we commission, develop, consume and evaluate online or computer-based learning. In particular, how can we create practical guidance for computer-based instruction when its technological underpinnings are constantly evolving? The technological world will not stand still long enough for us to understand its effects on our efforts to support learning.

New approaches in education, such as MOOCs, have the potential to demolish the rule book on how we approach educational interventions

We know that where technical standards for e-learning technologies, such as virtual patients (VPs),

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do exist, they allow for meaningful comparisons between instructional designs.[6] However, given that our understanding of what makes a good VP is still comparatively rudimentary, are technical standards promoting opportunities for innovation or holding them back? Although technical or software standards may help to define an approach for a programmer, researcher or academic, they are likely to be less relevant to the educator who is trying to produce the most authentic educational experience. Technical standards are beneficial in a relatively stable technical environment in which the exchange or interoperability of data is a goal. However, in areas that have yet to reach anything like stability, standards may be more of a hindrance than a help, or, worse still, an irrelevance. For example, there are currently no formats for the exchange and archiving of MOOCs, yet this is not holding back the explosion of MOOC-based approaches.

How can we create practical guidance for computer-based instruction when its technological underpinnings are constantly evolving?

These recommendations of Lau[2] and others[1] are consistent with our own research findings[7] using an e-learning technology, the VP. Lau[2] stresses the importance of educational objectives for learners. Our own grounded theory qualitative research identified this as an important factor, with learner objectives varying considerably among individual students and year groups, despite a uniform curriculum and training approach.[7] We attempted to set goals for students in different areas, such as the application of basic Bayesian reasoning to the interpretation of common laboratory investigation results. Interestingly, some trainees did not feel these activities were appropriate. We were able to subsequently evidence that this negatively impacted on these individuals' use of the VP and performance in clinical reasoning tasks. Lau[2] provides a framework to help us understand how we might deal with the challenging problem of setting learner goals. Interestingly, we also identified a potential pitfall with any approach for setting learner objectives. This relates to the increasing pressures on educators and the attractiveness of the CBTM's ability to deliver a measurable, auditable educational intervention at comparatively low cost.[8] We found evidence that this may influence the goals and behaviours of students, particularly in any mandatory activity. Our own work attempts to measure, describe and model how these external factors at a faculty, institution or national level may influence students and learning experiences. Thus, although the instructional design framework described by Lau[2] clearly helps to inform CBTM design, it is also possible that learning theory may be superseded by factors outside the control of the author of the resource. We are yet to see metrics capable of evidencing learning theory in real-world educational environments in terms of participation, performance and collaboration.

Standards may be more of a hindrance than a help, or, worse still, an irrelevance

In summary, we know that computer-based learning works and that technology is likely to develop unpredictably. In turn, this will produce major changes in the medical education landscape in the coming decade. We do not know how the impact of new web-based delivery tools such as MOOCs will influence costs, effectiveness, collaboration or the sharing of resources. Educational theory is likely to help, as are individual contributions from different types of e-learning. Most health care professionals recognise and appreciate well-designed educational resources, but far fewer of us successfully or systematically apply evidence-based principles to instructional design. Lau[2] provides us with a compass and a map with which to navigate these educational challenges for the CBTM, but these developments bring with them further questions and challenges.

REFERENCES

1 Cook DA, Levinson AJ, Garside S, Dupras DM, Erwin PJ, Montori VM. Internet-based learning in the health professions: a meta-analysis. *JAMA* 2008;**300**:1181–96.
2 Lau KHV. Computer-based teaching module design: principles derived from learning theories. *Med Educ* 2014;**48**:247–54.
3 Mayer RE. Applying the science of learning to medical education. *Med Educ* 2010;**44**:543–9.
4 Kellogg S. Online learning: how to make a MOOC. *Nature* 2013;**499**: 369–71.
5 Parry M, Field K, Supiano B. The Gates Effect. 2013. http://chronicle.com/article/The-Gates-Effect/140323/. [Accessed 2 October 2013.]
6 Smothers V, Greene P, Ellaway R, Detmer DE. Sharing innovation: the case for technology standards in health professions education. *Med Teach* 2008;**30**:150–4.
7 Bateman J, Allen M, Samani D, Kidd J, Davies D. Virtual patient design: exploring what works and why. A grounded theory study. *Med Educ* 2013;**47**:595–606.
8 Bhutta ZA, Chen L, Cohen J *et al.* Education of health professionals for the 21st century: a global independent commission. *Lancet* 2010;**375**:1137–8.

