Editorial

Educating Chemists for the Future

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A quiet revolution is in the air, with consequences that are just beginning to be visible. The revolution is the migration away from paper towards the rich and enticing environment of the electronic page. As in any revolution there will be losses of some cherished familiarities. But overall there will be a gain and an enrichment of the learning experience that we educators and our students should welcome. In this Editorial I shall reflect on the likely consequences and the responses that we instructors (and authors) are likely to make as the wave of revolution floods towards us.

Almost certainly, our initial response is likely to be a mixture of indifference and expressed, but I suspect not entirely heartfelt, enthusiasm. The indifference will arise from the supposition that not very much will change. Don't believe it. As the richness of the e-book environment develops, so the whole character of education will change. That should be the spring to drive our enthusiasm.

The bright new environment

I shall focus on the impact of electronic versions of textbooks (e-texts), which have a much richer environment than simple e-books. The advantages of e-texts over paper textbooks do not need to be rehearsed in detail here. Briefly, they encourage interactivity and the deeper immersion of the student in the

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process of learning. Current e-texts are very primitive in many respects and the various species of e-reader currently available are no doubt a passing phase, with tablet-like devices and smartphones giving a much richer experience with their color screens and much more capable operating systems. Maybe the perfect combination will turn out to be a tablet-like device with an e-ink color screen, or even many such screens, to enhance the browsing experience.

Once e-readers of sufficient power and sophistication are available, they will undoubtedly render paper textbooks obsolete. They will also prove enormously challenging, which is another way of saying 'expensive', to feed with suitable educational material. So, don't expect the e-text world to be less expensive than the paper world. It goes without saying that the e-texts will be in full color, with immersive three-dimensional displays, animations, and audio and video content.

> **Tablets blur the distinction between learning and recreation.**

Interactivity will be present in a variety of forms. One form, which is already present in some versions, will be the ability of the instructor to augment, modify, and re-order the content. Another will be devices that encourage the student to explore the material at greater depth. Most importantly, though, there will be tutorial wizards, 'e-tutors',

that will guide the reader into deeper understanding and personalize the level of instruction as the e-reader learns the types of difficulties that the student displays. It could be that the reader has to pay for this kind of help, with micropayments. There are obvious opportunities for publishers to sell a skeleton text and then to make money by providing many apps and plug-ins, or even just revealing the answer to a problem. Social networking will be embedded, to encourage collaborative learning.

What so far has eluded the chemical education world, and will be a fine step forward on e-texts in due course, is an immersive gaming approach to the education of a chemist. It has been said that one educational advantage of tablets is that they blur the distinction between learning and recreation, it being so easy to slip from one genre to another in the same working space. If that is so, then there is a seriously important opportunity for building an educational game into an e-text environment. (As an aside, I hope it will be possible to do so without adopting the violence so characteristic of current games.) The problem, of course, is cost. Modern games are graphically so sophisticated because their writers have access to sophisticated, costly engines; it will be essential to strive for the same level of presentation, for otherwise the student will be disappointed and think of the e-text as an amateur, dispiriting effort.

One consequence of the adoption of adaptable e-texts is that there will be little role for the traditional lecture and, therefore, the traditional lecturer. With

an e-tutor embedded in the e-texts, perhaps presented as a reader-selected avatar (Albert Einstein?, Lara Croft?) and available from the Cloud, there will be no further need for lectures or time-tables. e-Texts will also be developed to monitor the student's development and, perhaps, commitment.

An advantage of this university-in-a-textbook vision is that good practice and excellent education will become available everywhere, as students in developing countries gain access to instruction developed in collaboration with the finest institutions around the world and, perhaps through social networking sites, collaborate with other students elsewhere.

The devolution of learning that this vision of e-texts represents brings into the limelight another problem: how to examine. That is already a problem, because techniques of examination have not kept up with techniques of instruction. A great deal of instruction is now, quite rightly, computer-based: that in-

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How do we examine students taught with e-texts?

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cludes molecular graphics, computational chemistry, and mathematical software. But instructors currently find it difficult to bring themselves, once again perhaps quite rightly, to allow laptops into the examination hall and so do not always examine what they have taught. This problem will be exacerbated with the next generation of e-texts. It will be necessary, and this is perhaps a role for the chemical education profession, to develop modern modes of examination

that properly reflect the modern modes of instruction that are becoming available.

And the downside?

Are we at heaven's gate, or is there a touch of hell on the horizon that I am scanning? From an author's point of view, the prospect of writing a textbook is already daunting: it is at least doubly daunting to consider developing—writing is hardly the term—an e-text with all its bells and whistles. Publishers are already finding it difficult to persuade research chemists to set aside the bench for a considerable time and turn to writing paper textbooks: they face a mammoth task to persuade chemists with a research career in mind, or against the advice of their research-income-alert head of department, to consider developing an e-text.

Moreover, whereas new editions of paper textbooks come along at (to an outside observer) a leisurely pace of about one every four years (to the author, that is already grindingly oppressive), e-texts will be continuously redeveloped, and editions will give way to fractional versions and almost continuous updates. The task of authorship will become continuous. Few, perhaps, will be able to commit.

Then there is the larger question of authorship. Currently it is conceivable even for a major textbook to be written by a single author with the advantage (perhaps) that that implies: there is a single coherent voice, a clear point of view, and, for better or worse, a personality. It is barely conceivable that an e-text, as I am imagining it, could be

developed by a single person. There may be an overlord, a kind of director of the enterprise, an admiral of the fleet, but so many skills and talents will be required to produce a multimedia e-text that it seems inevitable that a team of contributors will be involved.

One other hint of hell on the horizon that troubles me with my perception of the future is that an e-text will make learning too easy. A great way to learn is to travel through difficulty, grappling with difficult concepts until they are mastered. If an e-text makes grappling too easy, like building an elevator to the summit of Everest, then learning might be superficial, not deep and lasting. And likewise, what of imagination? If every concept is developed visually, by analogy, and by animation, what is left to encourage the student to develop his or her own imaginative vision of the concept? This point troubles me greatly, and I would very much like to know whether research shows that computer software currently encourages imagination or quenches it.

Welcoming the future

But let us not in conclusion be negative. The prospect of a fully developed e-textbook is truly exciting. It is involving, encouraging, and if well-constructed, then a replacement for lectures. It will even, if the vision is large enough, blur the boundaries between disciplines, and allow a reader to migrate across the whole of science in a single package. It will be very interesting to see what kind of scientist the new educational experience will produce: not, I hope, one detached from reality.