Graduate education on the Internet

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The Internet can be advantageous for specialist graduate and research-based teaching and learning. Positive points include: (a) faculty members can consult students interactively about the choice of material; (b) students can access/download notes and interact with faculty members, independent of location and time; (c) students can access web pages put up by other groups working in related areas, and can incorporate them into course projects; (d) the fact that specialist courses cannot be given in person each term/semester/year becomes relatively unimportant: they can still be studied at other times; (e) further material, including working programs/models can be prepared/explored as part of undergraduate projects, and/or in collaboration with other institutions.

Experience has been gained delivering graduate courses and individual lectures on surface and thin film physics, and quantum physics, during 1996–8 in an international context, and attending and contributing to related workshops. Points needing further discussion and resolution include: accreditation and costing between institutions, the nature and extent of copyright problems, and most useful forms of student interaction. More details can be found at http://venables.asu.edu/grad/index.html.

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to the select band of 12 who took the course for credit, but in fact eased myself into putting the course notes on the Internet (i.e. the World Wide Web), and taking on students in Canada and Sussex to follow the course at a distance as an experiment. The major problem for the Canadian student was that initially he did not know me personally, and therefore felt inhibited in posing questions via e-mail. We arranged to meet at the American Physical Society March meeting over a drink with his supervisor to discuss what next. After that we had no problems, and a productive e-mail correspondence ensued, with assignments submitted as e-mail attachments, or via the regular mail.

Further intermittent work on the notes during 1996–97 was followed by a course of graduate-research lectures on Adsorption and thin film growth mechanisms given at EPFL in the autumn of 1997. I am now offering a Surfaces and thin films course worldwide for the spring semester 1998, as an official ASU Internet-based course, which will use all these resources built up over the last three years and develop them further. I am also teaching a graduate Quantum physics class, which will build up a more modest collection of resources as the semester proceeds.

The details can be found from my home page, whose address is given in the abstract. The graduate course notes themselves can be found starting from the second entry on my home page, http://venables.asu.edu/grad/index.html, whose format is shown in figure 1. This page is divided into courses and web-based talks. Following the hyperlinks leads to the course details, and, in the case of the surfaces course, to individual lectures and other web-based resources. As I write, I have some 33 lectures directly accessible, each of which are 4–7 pages of notes and most of which can be downloaded (by ftp in Word 6.0 PC format) from
These notes refer to diagrams which, in general, have not been put on the web. A test case, section 1.5, part of which is illustrated in figure 2, was done to convince myself that I could do it relatively simply, using Paint Shop Pro to produce .gif files for diagrams and passages containing equations. But the fact remains that I have chosen not to in general. Students following the course are given these diagrams in class or have them mailed to them. As HTML languages and techniques improve further, this will be less and less of a problem; for example, Greek letters can now be incorporated via programs such as Netscape’s Composer, whereas when figure 2 was produced, these Greek letters had to be incorporated via small gifs.

In preparing my EPFL course, I uploaded the notes to the ASU computer one day before the class, and many participants downloaded them in time, i.e. twice across the Atlantic, often ending up in the office next door. So is this just a Book-on-screen (Bos), or a complicated version of a photocopier? Well, no, I don’t think so. The lectures themselves are hyperlinked to each other, and refer to other external web resources, plus an extensive set of references, which has been built up in parallel but finished later. Some students, while really interested, couldn’t attend the lecture, but were pleased that they could study the notes in their own time. Thus the lecture itself, which may or may not have been useful, fascinating, etc, an event localized in time and space, is only one part of the story: the resource so created is not localized in either dimension.

Moreover, links to other laboratories and research work elsewhere can give the notes a dynamism which the printed page lacks. I give two examples by way of illustration: (1) in 1996, a student did a course project involving access to a Danish web site and downloading programs to run locally. This gave him much more insight into the topic of effective medium theory than I could have given on my own. The hyperlink in the course notes (for section A1) meant that other students were also informed, and could pursue the topic themselves if they wished; (2) I have recently put up, and linked to my course notes, the set of pointers [3] to selected major research groups (including the Danes), references and images, as shown in figure 3; this resource is available for past students and other members of the community, as well as future students for whom it is primarily intended.

In summary, the web is a powerful instrument for collaboration on an asynchronous basis. Students can download material, and faculty members can interact with the student anywhere; most importantly, they don’t have to be awake or concentrating at the same time, in contrast to the various forms of interactive video-based classrooms involved in synchronous distance learning. If they need to talk face to face, they can arrange it electronically or otherwise to suit themselves. Moreover, students can access material put up by other groups working in related areas, and can incorporate such material into projects; this means that the student is in principle not limited by the understanding of the local teacher. The combination of projects and resources is powerful, because projects by current students, suitably filtered, can become resources for future students.

This concept can be extended, as further material including working programs/models can be prepared/explored/linked as part of final-year projects (UK) or research experience for undergraduate (REU) programs in the USA. During 1996 an ASU student, Jeremy Piwowarczyk, worked with me on a physical adsorption project which can be seen in the /reu directory, by clicking in the second paragraph on my home page. This continued after the semester by e-mail and file exchange when I was in England. Jeremy has now moved on to other things, and this project is not finished in any real sense; but I am discussing continuing it in collaboration with experts at two other institutions, and it could well be a student elsewhere who takes up the challenge.

The point is that the need to cover every topic locally has simply disappeared. This should be especially liberating for research groups in small or isolated departments, where the opportunity to present specialist courses occurs rarely, and the students really do need to interact with the outside world. I remember a discussion I had in a café in Cambridge, Mass., some years ago with MIT post-docs and graduate students, who were hosting me for a seminar. They were telling me what a wonderful place Boston was, and how all the resources they needed were immediately to hand. While this had a certain cozy logic, I attempted...
1.5 Introduction to Surface Electronics

... (part of page) ...

· Work Function

This is the energy, typically a few eV, required to move an electron from the Fermi Level, EF, to the vacuum level, E0. The work function depends on the crystal face (hkl) and rough surfaces typically have lower work function, \( \phi \), as discussed later in Section A1.

· Surface States and related ideas

A Surface State is a state localised at the surface, which decays exponentially into the bulk, but which may travel along the surface. The wave function is typically of the form

\[
\psi(x) \propto e^{-i(k_z z)} e^{i(k_x x)},
\]

where, for a state in the band gap, \( k_z \) is complex, leading to decay away from the surface on both sides.

(continued)...

Figure 2. Top: part of the web page for section 1.5, containing simple diagrams in .gif format. Bottom: the corresponding HTML version 3 code. Note that sections containing equations and Greek symbols are also encoded here as gifs. HTML version 4 removes some of these limitations, which may disappear entirely in future versions.
Web-based Resources in
Surface Physics and Thin Films

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This file contains a list of web-based resources for use in connection with my graduate course, web-based articles and talks. If you have items you would like me to add, please email me. However, I am aiming to be exemplary rather than comprehensive, so please don't be offended if I leave material out. Latest version of this document 23 December 1997.

Web-based graduate education

- PBS Seminar, April '97
- Stanford advice to research students
- AAST Distance Learning
- If you don't find what you want, try a search. I have given some tips on how to do this in my talks, e.g. at Other graduate resources.

Links to Instrument development and charged particle optics

Links to Surface theory and simulation codes

Links to Experimental Group Results; mostly STM

Lessons to be learnt: where to next?

Why go to this trouble? My underlying reason is that faculty members are under pressure, in both the US and the UK, to earn their living by standing up in front of undergraduates, preferably in large numbers. In larger departments, specialist graduate courses have typically been given every two years, but it could easily, and often does, slip to a lower frequency. When this happens, then the necessarily small graduate classes become completely useless. We are in effect saying to our students ‘we will give you a course in your specialist area, but it may take place while you are writing your thesis’. Use of the web turns this argument on its head. If there is a one-line message for faculty members, it is to use an infrequent event to create a continuously available resource.

We should also note that presentation does not really have to be flashy: high quality
information is what is required, since all (western science) graduate students exist in a computer-rich environment, and in general it could be argued that they have sufficient motivation to succeed. Downloading unnecessary graphics is in any case a pet hate of the online community; many of us in the US university environment simply do not realize how slow access can be over a regular phone line. They can also be astonished that local calls outside the US are not free, and I have had to request that a simple graph be reduced to black and white, please, rather than transmitted in 16 million colours. At the level of kiss (‘keep it simple, stupid’) there is no real need for outside technical assistance, beyond good relations with your computing staff/webmaster, and this is the message I have tried to stress; appropriating an American slogan: just do it!

The question: how fancy? of course won’t go away, and at last year’s workshop on materials education in Boston [7] there was some evidence that graduate student study should be accompanied by extensive graphics and a soothing sound card, and if possible by clever Java applets and even virtual reality (VRML); indeed one could argue that the medium itself demands no less. Some of these exhibits were impressive, and required much work from someone, even if not necessarily (though usually) the faculty member concerned.

There are now many simulations available on the Internet, especially Java applets of various types, which I may well find useful for my quantum physics class. In my paper for that meeting [8], I did, however, raise the question of whether faculty efforts, unless very carefully thought out, may not be in danger of trying too hard: whose music, whose applets, whose VRML? There is a question of ownership: why not get the student to add the music, and to do their assignments using Java or ...? This is a (generational) question with implications for the future organizational structure of departments: I now know two people who have actually been hired to provide web-based educational services, and this is changing fast. All else so far is individual enthusiasm, with or without student helpers and/or projects. Meanwhile my own recipe is to turn projects into resources; over the medium term, we all need to think about these issues carefully.

An interesting new development is that young faculty members in the USA who receive a prestigious career development award—the old presidential young investigator (PYI) award transformed—are required to pursue an educational project in parallel with their research. Not surprisingly, several are experimenting with the Internet; an ambitious example [9] is a recently developed/developing graduate course on organic molecular conductors. For established faculty members, the primary question is how to find the time, and there is no easy answer, except to note that there are substantial opportunity costs for not doing so. In my own case, I am clear that this type of work fits well with a somewhat delocalized way of life; but one should note that I am not currently running an experimental research group nor doing any major administration. If I were, I would need more assistance, mainly with presentation.

Discussions with individual faculty members on whether they themselves should get involved elicit various responses, from defensive (jobs, etc) through too busy, to concerns about tenure and the nature of a university. Practitioners and enthusiasts simply think this is a moving train which either you catch or you don’t. Although there are real issues lurking here, I tend to side with the latter in general; in particular, I think the case for using the Internet for specialist graduate education in the way I have described is overwhelming; for core graduate courses the case is merely strong. Faculty members should argue that good courses of this type take at least two years to construct: the first stab requires considerable modification in the light of student reception.

Recurring points for discussion and resolution include copyright, accreditation and costing of off-campus students, and the establishment of useful forms of student–student interaction. Copyright is a real issue, but people vary on how they interpret it, and there does appear to be some latitude (as well as uncertainty) as to whether and how far fair use applies [10]. In preparing for my spring 1998 course, I tentatively e-mailed selected colleagues to ascertain whether any of their graduate students would be interested in following such a course, and whether their institutions have any way of paying for, and accrediting, such coursework done over the web. Reactions vary widely from instant unreserved approval to the silence implied by (in my Eudora e-mail package): click transfer and then trash. This could be the academic junk mail
of the future, or it could be that the mechanisms for a sensible response are not yet in place.

As in many areas, the Open University has arguably the most extensive experience, mostly using First Class conferencing software and the web for their discussion environments; others are experimenting with Lotus or WebNotes [11]. For the numbers on specialist graduate courses, I am not yet convinced that this level of investment is necessary, and it certainly shouldn’t be used as an excuse for not proceeding. A simple e-mail list will do to start with, and if someone on the course wants to experiment, well, then we may have turned a project into a resource.

In starting this mode of teaching as an experiment in real time, I don’t know how it will play out over the semester and the longer term. Am I really going to have large numbers of students around the world (in which case I have some serious systems thinking to do, especially about examining and project assessment), or will I have one or two (in which case I can be a lone individual, in Diana Laurillard’s sense [12], but others might wonder whether it was worth all the fuss)? It will be interesting to see where this all leads, and where the balance between textbooks, conventional and/or videotaped lectures, and web-based resources is struck. My own feeling is that it is here to stay, but that individuals like myself, who start via enthusiasm, will need some kind of developmental resources and structural solutions to remain competitive.

Acknowledgments

I am grateful to EPFL, Lausanne, Switzerland, for recent hospitality, and to Klaus Kern for his support and encouragement of my web teaching experiments. Thanks also to Lois Lehman and Lee Rogers for departmental computer support at ASU, to Tony Durrant and John Baglin for permission to borrow material from articles prepared for different audiences, and to Diana Laurillard, Darcy Clark and Janice Musfeldt for useful correspondence.

Received 12 December 1997
PII: S0031-9120(98)90828-0

References

[3] The Danish website is run by Per Stolze (http://www.fysik.dtu.dk/camp-sd.html).
My own lists are accessible from http://venables.asu.edu/grad/appweb1.html
[4] The web site http://www.utexas.edu/world/lecture/ contains a listing across all subjects, including physics, but at January 1998 they are almost all undergraduate courses.
The engineering college at ASU is using Webnotes extensively from http://forum.eas.asu.edu/