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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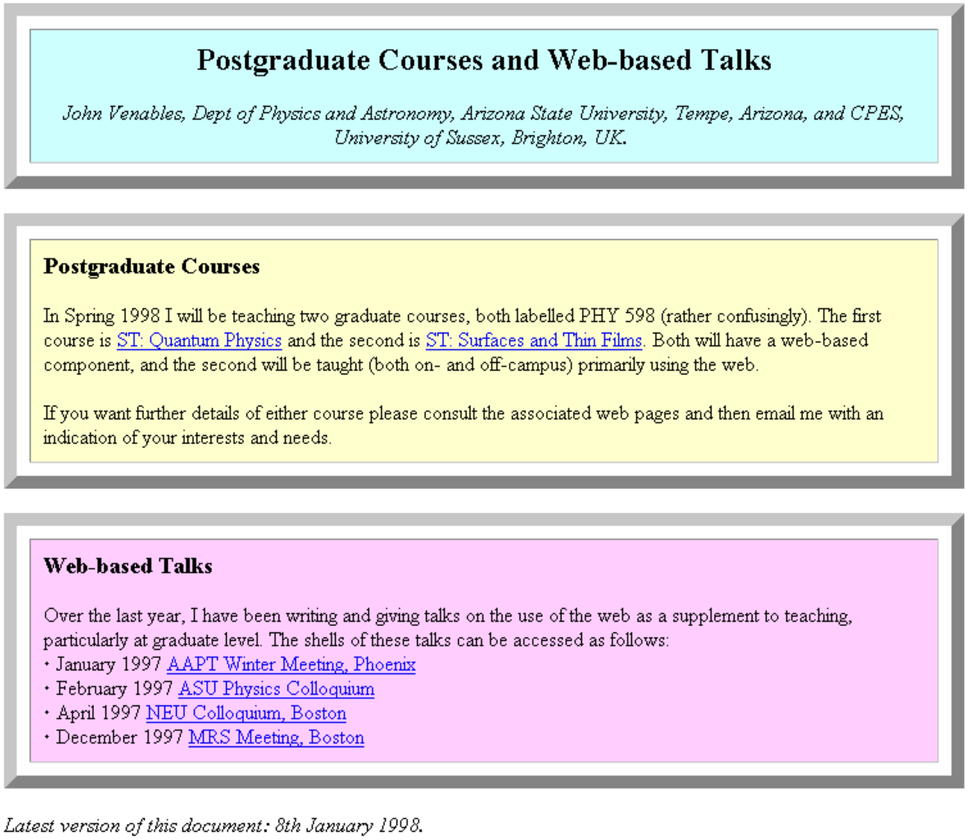
The Internet can be advantageous for many kinds of teaching and learning in higher education. But most efforts to date are experimental, provisional, and we are all very early on the learning curve. My general contention is that now is the time to consider widely some of the pedagogic and other issues, based on the experience of those who have been experimenting over the last three years or so. In the UK, the educational weeklies have been covering these issues in depth over the last 18 months, and I am not about to repeat the implied threats to universities if they don't take open learning seriously [1, 2].

The focus of this article is *graduate education*, with emphasis on specialist courses. I write as someone who has used the Internet for both undergraduate and graduate courses and who has participated in some staff development sessions and educational workshops devoted to the topic, since January 1995. I do not have special expertise, in the sense that I have not done anything technical that could not be done by any member of faculty with enough interest and time (a big *if*, but see later). However, I have been putting in the time and consulting widely. The next section describes this experience and where it is leading, before trying to draw some lessons in the final section.

Graduate courses in *Surfaces and thin films* and *Quantum physics*

In the spring semester 1996, I taught a course in *Surface physics* at Arizona State University (ASU), which I had given for several years to 15–30 graduate students with physics, chemistry, materials science and engineering backgrounds. I could have had an easy semester repeating myself



Postgraduate Courses and Web-based Talks

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Postgraduate Courses

In Spring 1998 I will be teaching two graduate courses, both labelled PHY 598 (rather confusingly). The first course is ST: Quantum Physics and the second is ST: Surfaces and Thin Films. Both will have a web-based component, and the second will be taught (both on- and off-campus) primarily using the web.

If you want further details of either course please consult the associated web pages and then email me with an indication of your interests and needs.

Web-based Talks

Over the last year, I have been writing and giving talks on the use of the web as a supplement to teaching, particularly at graduate level. The shells of these talks can be accessed as follows:

- January 1997 AAPT Winter Meeting, Phoenix
- February 1997 ASU Physics Colloquium
- April 1997 NEU Colloquium, Boston
- December 1997 MRS Meeting, Boston

Latest version of this document: 8th January 1998.

Figure 1. The author's graduate course page (http://venables.asu.edu/grad/index.html) from which the graduate courses described can be accessed.

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 within the web page.

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 cosy logic, I attempted

Notes for PHY 598 Sect 1.5 (Venables)

Click to ftp this document in Microsoft Word 6.0 Format

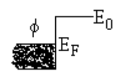
Lecture notes by John A. Venables. Lecture given 1 Feb 96. Notes updated 29 May 96

1.5 Introduction to Surface Electronics

...(part of page)...

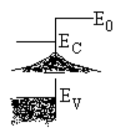
· Work Function

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, ϕ, 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



$$\psi \approx u(r) \exp(-i\, k_\perp |z|) \exp(i\, k_{//}\, r),$$

where, for a state in the band gap, $k_\perp$ is complex,
leading to decay away from the surface on both sides.

...(continued)...

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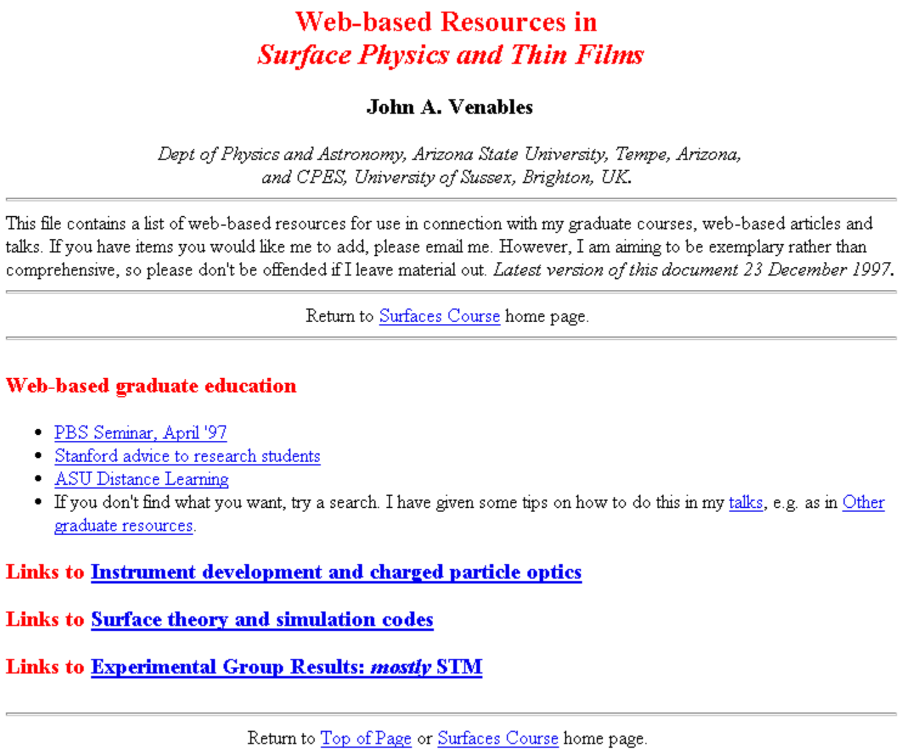
<HTML>
<body bgcolor = "FFFFFF">
<title>PHY 598 (Venables) Sect 1.5</title>
<H2>Notes for PHY 598 Sect 1.5 (Venables)</H2>
<A HREF= "ftp://groucho.la.asu.edu/pub/sphy/sect15.doc"
<B>Click to ftp this document in Microsoft Word 6.0 Format</B>
</A><P><hr>
Lecture notes by John A. Venables. Lecture given 1 Feb 96.
Notes updated 29 May 96<P>
<H2>1.5 Introduction to Surface Electronics</H2>
...(part of page)...
<P><H3><LI> Work Function</H3>
<IMG SRC = "sect151.gif" VSPACE = 2 Align = right>
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,
<IMG ALIGN = top SRC = "sect152.gif" VSPACE = 1> as
discussed later in <A HREF = "sectA1.html"> section A1.</A>
</P>
<H3><LI> Surface States and related ideas</H3>
<IMG SRC = "sect155.gif" VSPACE = 2 Align = right>
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<P>
<IMG SRC = "sect156.gif" VSPACE = 1><br>
leading to decay away from the surface on both sides.
...(continued)...
</HTML>
```

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 courses, 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.*

Return to Surfaces Course home page.

Web-based graduate education

- PBS Seminar, April '97
- Stanford advice to research students
- ASU 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. as in 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

Return to Top of Page or Surfaces Course home page.

Figure 3. Web-based resources file linked to my course pages in preparation for the 1998 Internet-based course on *Surfaces and thin films*. From here you can access the major research groups worldwide, *inter alia*, in charged particle optics, surface theory and simulation codes, and major surface experimental groups complete with online STM images and movies. This resource will be extended during 1998 with student project input.

to convince them that I was in fact better off, because *I knew* that I needed to follow what they were doing, but *they thought* (implicitly of course) that they didn't need to know what I was doing. I'm not sure I made a lot of headway then, but the same argument reasserts itself forcibly in the Internet environment.

There is currently a disparity between the number of undergraduate courses (several) and graduate courses (very few) on the web, a point that can be checked in real time by visiting the World Lecture Hall site at the University of Texas [4]. An ambitious program of exposing undergraduates to research using the Internet is being pursued by several physics faculty members who attend the American Association of Physics Teachers (AAPT) meetings [5]. In the same vein as the previous paragraph, they report that they receive as many hits per month as more prestigious institutions [6]. This is a reasonable first-order figure of merit in the online world.

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.

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[1] Greenhalgh T 1996 *Times Higher Educ. Suppl.* 8 November

[2] Venables J A 1997 *Times Higher Educ. Suppl.* 14 March, Multimedia section

[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.

[5] Donelly D 1996 *Comput. Phys.* **10** 532–41

[6] Christian W 1997 *Comput. Phys.* **11** 436–41 (http://webphysics.davidson.edu)

[7] Abbaschian R, Baglin J, Constant K and Stoebe T 1997 *Workshop on Materials Education* MRS Fall '97 meeting, Boston (1998 *J. Mater. Educ.* in preparation)

[8] Venables J A 1997 paper OO2.7 at MRS Fall '97 meeting (1998 Specialist graduate education using the web *J. Mater. Educ.* submitted)

[9] Musfeldt J *et al* 1997 paper OO2.9 at MRS Fall '97 meeting (Lee J *et al* 1998 A distributed network-based course in organic molecular conductors *J. Mater. Educ.* submitted) (http://chemiris.chem.binghamton.edu:8080/MUSFELDT/musfeldt.html)

[10] Clark D J M 1997 paper OO2.1 at MRS Fall '97 meeting (1998 Shared educational resource development for MSE *J. Mater. Educ.* submitted)

[11] An Internet-based course on object-oriented computing, using First Class software, is at http://www-cs.open.ac.uk/∼m206/m206home.html
The engineering college at ASU is using Webnotes extensively from http://forum.eas.asu.edu/

[12] Laurillard D 1993 *Rethinking University Teaching: A Framework for the Effective Use of Educational Technology* (London: Routledge) p 2