

Strand 2: Innovative Delivery: Methods and Approaches

Paper 15:

Structural Biology Courses on the Internet

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Introduction

- During the next ten years, we envisage fundamental changes in the provision of higher education. Firstly, the widespread use of information technology will enable students to study whenever and wherever they wish. Secondly, the pace of technological change in society will require a workforce where lifelong learning is part of the culture. The era when students in higher education are typically under 25, living away from home and studying full-time, must be coming to an end. The Internet is an important medium for the delivery of educational materials and, increasingly, complete courses. The Department of Crystallography at Birkbeck College, London, has been in the vanguard of these developments. For the past three years, we have been running an Advanced Certificate course entitled *Principles of Protein Structure using the Internet*¹ [1,2] (subsequently referred to by the acronym PPS). This was one of the first tutor-assisted, accredited, University level courses to be taught entirely over the Internet, and is certainly the first in biomolecular sciences in the UK. In 1997 it received an award from the Universities and Colleges Information Systems Association (UCISA) for innovative use of the World-Wide Web in higher education. This year a second Internet-based course, Advanced Certificate in Protein Crystallography on the Web², acronym PX, was introduced. Both these courses are of twelve months' duration and of final year undergraduate standard, although almost all their students are graduates. Successful students receive the award of

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an Advanced Certificate from London University, which is a graduate level qualification approximately equivalent to half a UK Master's degree.

This way of providing education differs from more traditional types of distance learning in that both delivery of course material and student-tutor interactions take place wholly using Internet and associated multimedia technologies. Our students, who may come from any country, may study at home, at work or at college, and set their own hours of study. The only equipment required by the students is a standard personal computer or workstation, and an Internet connection. This technology is readily and relatively cheaply available. Although all the course tutors are based at Birkbeck, the PPS students also benefit from the involvement of a group of consultants. These people are usually academics from the UK or abroad who conduct tutorials on specialised topics in the syllabus and are available to answer students' questions by e-mail. Some consultants also assist in the electronic administration of the courses.

Staff of the Department of Crystallography have been developing software for the display of macromolecular structure for use in teaching since 1993. The growing popularity of the World Wide Web led to the next step: of delivering this software over the Web for students' use away from Birkbeck. A pilot version of the PPS course was launched early in 1995 to evaluate the possibilities of these technologies for the delivery of a full-scale course. This experiment in "virtual education" proved successful: of the 270 students from 27 countries who took part, 90 stayed with the course until the end. The average number of students registered for the PPS course during the three years in which the accredited course has run is over 68. 66 students, from eighteen countries - and four continents - have registered for the current course. There are fourteen students from five countries taking the Protein Crystallography course in its first year of operation. The dropout rate for the accredited courses has been low. (See Table 1 and Figure 1 for a full breakdown of student numbers.) In order to be accepted for either course, students need a UK

bachelor's degree in any science subject or its equivalent. A few undergraduate students have been accepted on the courses. These are typically from central European countries such as Poland, where some undergraduate programs are up to five years long and lead to the award of the equivalent of a Master's degree. Students are expected to have regular access to a standard PC, Macintosh or Unix workstation. The minimum acceptable specification for a PC is currently 50MHz 486 with 8Mb RAM with a reliable Internet connection and access to the WorldWide Web via a modern graphical browser such as Netscape or Internet Explorer (versions 3 or 4). Most of our students use the PC and Unix platforms and these are the best supported by the technical staff at Birkbeck.

Course Contents

- In both courses, the course syllabus starts with an introduction to the use of Internet tools and protocols. The PPS course syllabus includes basic protein structure, protein synthesis, elementary bioinformatics (DNA and protein sequence analysis) and the relationship between protein structure and function. The Protein Crystallography course is described in its mission statement as "Protein crystallography for the biologically oriented scientist". Its syllabus covers the fundamentals of protein structure appropriate to protein crystallography, with a particular emphasis on the difficult - and vitally important - topic of symmetry, and the techniques and skills necessary to solve the crystal structure of a protein and to judge the quality of structures published in the literature. The choice of bioinformatics and protein structure, including crystallography, as the core scientific subjects taught reflects the growing importance of these subjects to industry. Structures of protein molecules are now being determined at an accelerating rate, driven by technological improvements and increased investment in molecular biology through genome projects. The design of novel drugs and vaccines depends on an understanding of the details of the relationships between protein

- 1 The URL for the current Advanced Certificate in Principles of Protein Structure is <http://pps98.cryst.bbk.ac.uk/>.
- 2 The URL for the Advanced Certificate in Protein Crystallography on the Web is <http://px.cryst.bbk.ac.uk/>

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sequence, structure and function. The pharmaceutical and biotechnology industries increasingly need personnel trained to a high standard in these techniques.

Assessment

- Formal assessment for students on both courses consists of an examination, which the students attend in person at one of a number of local centres temporarily established throughout the world. This is important, as students' identities must be verified. The students are also expected to submit a project. In the case of the PPS course, this consists of a simple resource written in HTML presenting and explaining some aspect of protein structure. Some examples of the best projects are mounted on the Web to give future students an idea of what is expected. Students of Protein Crystallography work on two shorter projects: the first is the critical reading and evaluation of a recently published crystal structure, and the second the use of molecular replacement techniques to "solve" a protein structure. Students also benefit from exercises set throughout the course, which currently do not contribute to their assessment. Tutors may use the interactive and multimedia functionality of the Web to set course-work exercises containing, for example, images of protein structures which the students are expected to manipulate. Answers to questions can be submitted via e-mail or hypertext forms. This electronic submission of answers permits automatic checks to be made on student progress. Each student on the Protein Crystallography course is assigned a separate user identifier, which they use to run calculations on the central computer facilities at Birkbeck for their project work. We have also provided multiple-choice quizzes with instant feedback as self-assessment exercises.

International Implications

- This new approach allows higher education in less developed countries to be provided at a fraction of the cost of building conventional campuses there, or of supporting students travelling to the West. The level of technology required to benefit from

the Birkbeck courses is increasingly available throughout less developed regions, particularly central Europe and the former Soviet Union, South America and parts of east Asia. Many students from some of these countries were able to participate in the pilot PPS course in 1995. However, the fees introduced for the accredited course, although much lower than those for similar, traditional courses, effectively removed access to the accredited course to these students in 1996.

Birkbeck College was awarded a grant from the Open Society Institute for two successive years, which has enabled it to offer bursaries for the PPS course to students from central Europe and the former Soviet Union. Nineteen students from Poland, Hungary and Lithuania were awarded bursaries for the 1997 course, and 21 students - the majority from Poland - are being supported on the current course. Furthermore, students attending small or poorly funded colleges in developed countries may gain from access to experts working at leading worldwide institutions. Although bursaries are not currently available for the Protein Crystallography course, this course is likely to prove extremely valuable in countries where the technique of protein crystallography is only now being introduced. A good example of this is the Czech Republic; the first protein crystallography laboratory there will open in Prague later this year.

Communications on the Web can suffer from delays due to network congestion, particularly for traffic across the Atlantic. This is particularly important in countries with relatively poor network connections. In particular, Internet connections between Poland and the rest of the world have recently become extremely slow due partly to network congestion in Warsaw. In previous years we have taken up offers from other institutions to mirror our course materials in order to minimise these problems. These sites took nightly updates of the PPS course and in addition to providing faster WWW communication, the mirrors give insurance against computer or network failures. However, since the teaching material for both courses is now password-protected, which makes mirroring technically much more difficult, the mirrors have been temporarily removed. We hope to be able to reinstate at least the Polish mirror (at the Poznań Supercomputer Center) before the end of this academic year, making it much easier for Polish students to follow both courses.

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Enabling Technologies

- The unique combination of Internet-based technologies used to deliver these courses has now been well established. Some of these have been available for many years but others such as the "BioMoo" virtual reality conferencing system [3] are quite recent developments.

The World Wide Web enables us to use high quality colour graphics in our teaching materials, which are essential in the study of protein structure. Although a large proportion of the course material has been developed "in-house", we have also provided access to high quality tutorial or reference material relevant to the syllabus available elsewhere on the Internet. We have eliminated potential copyright problems by referencing the material using hypertext links, with the permission of the authors, rather than copying it on to our servers. Very little external material is used in the Protein Crystallography course.

The study of three-dimensional protein structure is made easier by being able to rotate colour images of the molecules on the computer screen. In PPS we provide viewing software such as Rasmol [4] and associated scripts which enable students to rotate protein images on their computers. Rasmol is readily accessible over the Internet, can be easily installed on a wide variety of computer platforms and - importantly - it is free. Molecular movies are also provided; these are very useful for helping students gain an understanding of complex molecular processes such as muscle contraction.

All students, tutors and consultants on both courses subscribe to e-mail "discussion lists" relevant to different areas of the course. For example, a PPS student with a problem regarding the operation of course software will e-mail the technical discussion list and any recipient can reply with help. In this way the students are able to learn by helping each other. The students are also divided into tutorial groups (according to country of origin), each with about 15-20 students, and each tutorial group also operates a separate list. Messages on the lists are placed in an archive catalogued according to date and topic. Students can review these archives and follow discussions, which have taken place earlier in the course.

Interactive tutorials are a popular feature of both courses, although they are more widely used in the PPS course. These use "BioMOO" [3], a virtual-reality, interactive conferencing facility mounted at the Weizmann Institute in Israel. When a tutor (usually based at Birkbeck) and a group of students (who may be scattered throughout the world) are connected simultaneously to BioMOO, the tutor can write text which the students can see almost instantaneously and reply in real time. Both the tutor and students may also display Web pages showing an assignment, which forms the basis of the tutorial discussion. PPS students are divided into tutorial groups according to country of residence - and therefore timezone - to try to minimise the difficulty of fixing times for tutorial groups to meet in BioMOO. This system is not used in the Protein Crystallography course, where student numbers are much lower.

Future Developments

- There are still some legal, technical and administrative problems, which are hindering the wholesale acceptance of these teaching methods. One of the most serious of these concerns student assessment - when students and tutors never meet face-to-face, it is much harder to guard against plagiarism, or students collaborating on assignments - or even to ensure that the students registered on the course are those who take the examination. Issuing students with individual passwords, which is necessary for Protein Crystallography students, may be one way to minimise the risks. The qualification offered, the Advanced Certificate, is also much less well known than, for instance, the MSc, which is an international standard. Many potential students, particularly those located outside the UK, are unaware of the level of qualification it represents. We hope to verify officially the position of the Advanced Certificate as compared to the MSc. It may even be possible that students who take two courses in successive years -- such as the two PPS graduates from Poznan, Poland who are currently taking the Protein Crystallography course -- will be awarded a London University MSc without ever visiting London. Although Internet bandwidth is increasing rapidly, the equally rapid increase in "traffic" means that communication delays are unlikely to improve much in the foreseeable future.

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Recent hardware and software developments are already affecting the quality of our educational material and the ways in which the tutors, consultants and students can communicate. Applications written in Java can be used directly, over the Internet, on a variety of hardware platforms without needing installation. One of the first biotechnology applications written in Java, CINEMA [5] (a tool for aligning protein sequences), is now being used in teaching. As network bandwidth increases, MOO-type programs will increasingly incorporate "shared whiteboards" which will allow dispersed groups of people - for example, a tutorial group or a group of academic collaborators working on a paper - to make changes to the same document in "real time". We are also investigating the simultaneous use of audio communication. Use of the higher bandwidth communication provided by ISDN or cable to provide audio and video may enable us to verify student identity locally.

The grant from the Open Society Institute was awarded for two years only. However, we believe that it will be important to continue to offer bursaries to students from less developed countries. Many senior academics in Poland, which is rapidly developing and where the PPS course is now well-known, would be prepared to pay modest fees for their students as this would give the students an extra incentive to take the course seriously. We hope to be able to set the level of fees for students from those central European countries where accession to the European Union is likely in the medium term, to no more than the current level charged for "home" or European Union-based students. A smaller number of full bursaries may be offered to students from poorer countries. We intend to market the course on CD-ROM to pharmaceutical companies, for mounting on their corporate Intranets and are also developing further courses in bioinformatics and molecular modelling at MSc as well as Advanced Certificate level for both academia and industry.

References

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Table 1

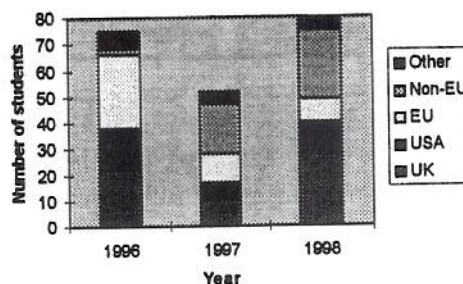
- Nationalities of students registered on Birkbeck's Internet based Structural Biology courses

Country	1996	1997	1998/PP	1998/PX
UK	22	10	23	4
USA	16	7	9	4
Italy	8	7	1	2
Germany	7	3	1	1
Poland*	0	8	17	2
Sweden	7	0	0	0
Hungary*	0	6	0	0
Australia	5	0	2	0
Lithuania*	0	5	0	0
South Korea	1	2	0	0
France	2	0	1	0
Spain	2	0	0	0
Belgium	0	1	0	1
Canada	0	1	1	0
Denmark	1	0	1	0
Japan	0	1	0	0
New Zealand	1	0	0	0
Norway	1	0	0	0
Portugal	1	0	0	0
Singapore	0	1	0	0
Switzerland	1	0	2	0
Brazil	0	0	1	0
Finland	0	0	1	0
Malta	0	0	1	0
The Netherlands	0	0	1	0
Slovakia*	0	0	1	0
Russia*	0	0	1	0
Bulgaria*	0	0	1	0
The Ukraine*	0	0	1	0
Total	75	53	66	14

* Students supported by bursaries from the Open Society Institute.

Figure 1

- Number of students registered on Birkbeck College's internet -based structural biology courses:



Notes

- No bursaries were awarded in 1996.
- The figures for 1998 here include both courses.
- "Non-EU" refers to all European countries (East and West) outside the European Union