PHYSICS AND DISTANCE EDUCATION

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INTRODUCTION

Distance education (DE) – the method of teaching and learning in which there is a quasi-permanent separation between students and their teachers – is playing an increasingly important role in the higher education provision of many countries. This article considers in turn the motivations for teaching at a distance, the nature of distance education, the particular challenges of teaching physics at a distance together with some specific examples of how those challenges have been met, and some of the less obvious benefits and opportunities that arise as a consequence of providing distance education in physics.

Most systems of distance education rely more or less directly on the available means of communication, so considerations of information and communications technology (ICT) will play an important role in much that follows. The article draws on examples from a number of institutions, but there is a particular emphasis on projects with which I have a personal familiarity, particularly those at my own institution, the Open University of the UK.

MOTIVATIONS FOR DISTANCE EDUCATION

There are several reasons for wanting, to teach at a distance. Some arise from the desire to meet the needs of students, particularly mature students (typically those over the age of 25), who are prevented from attending a conventional university by factors such as work or family commitments, living or working in remote locations, or physical disabilities of various kinds. Other reasons may concern national or institutional imperatives. For example, there may simply be insufficient space in existing universities to meet a growing national requirement for higher education places, or some special groups, such as members of the armed forces or embassy personnel, may require university level education independently of their location and in a manner that will not conflict with their other duties.

More economically driven motivations concern the costs of growth and access that many conventional university systems now generate. In the US, the cost of sending a son or daughter to a public university has been growing over a number of years. In the late 1990s it was already about 15% of median family income and it has increased over the decade since then. In the UK, the growth in higher education has caused successive governments to increasingly shift the cost of higher education from the state to the individual. The economies of scale implicit in many distance education systems provide a valuable counter to some of these tendencies. Indeed, where distance education is carried out in a way that complements conventional education, the sharing of staff and facilities (laboratories for example) can significantly increase the overall efficiency of a national higher education system bringing benefits to all concerned, including taxpayers.

Whatever the reason, the growth in distance education has been such that for some educational providers the idea of making existing courses available to remote learners, or of producing courses specifically for such learners, is almost automatic.

THE NATURE OF DISTANCE EDUCATION

The motivations listed above lead most university-level distance education systems towards flexible study patterns, usually on a part-time basis. But even within these general tendencies, distance education may still be provided synchronously or asynchronously. The synchronous mode requires students to be involved at some scheduled time (in order, for example, to participate in a tele-conference or an on-line tutorial). The asynchronous mode imposes fewer constraints since it only requires the completion of certain tasks (such as reading a book or performing a specified experiment) by a prescribed deadline. Courses may be taught by either of these modes, or by a combination of the two. The suitability of each mode will depend on the task in hand, the students involved, the desires of the teacher and the availability of the appropriate educational technology.

Asynchronous distance education first arose when national postal systems made ‘correspondence tuition’ a practical possibility. The arrival of radio and television broadcasting prompted the creation of synchronous mode ‘schoolrooms of the air’ in countries with widely dispersed populations such as Australia and Canada, and the proposed ‘university of the air’ in the UK. However, with the arrival of the internet and the world wide web, combined with cheap audio- and video-recording technology, the delivery of good quality distance education has become a cost effective option for teachers and learners in almost all developed and developing countries.

Irrespective of technology, the most characteristic feature of distance education is the separation (in space and/or time) of the teacher and the learner. Nonetheless, there are often other separations involved that are equally important. For example, the students are quite likely to be separated from each other, making group work difficult and raising the possibility that learners might feel isolated. Also, learners may be cut-off from important learning resources such as libraries, laboratories and museums. Distance learning programmes must generally be designed to overcome these effects so the features common to many successful DE programmes are:

Carefully designed learning and assessment materials, often specifically designed for isolated learners.

Use of ‘blended’ media; including print, TV, radio, telephone CD, DVD, WWW etc to produce an especially rich learning environment.

Some individualised student support (tuition, marking, course selection advice etc.) possibly delivered face-to-face. or else by phone or on-line.

The absence of frequent face-to-face contact with a teacher can have the effect of making the institution responsible for providing the distance education seem especially important. Hence, it is often the institution (rather than the individuals concerned) that is seen as responsible for:

Planning, producing and distributing learning materials.

Providing and coordinating student support.

Assessing learning.

Guaranteeing the quality of processes and outcomes.

Of course, in higher education a university is almost always formally responsible for these activities, but in reality responsibility is delegated to the teachers with whom the students have direct contact. This is often not the case in distance education.

The assurance of quality is of importance in almost all contemporary systems of education, but it is particularly important in distance education where students are less likely to have the facility of questioning their teachers directly. It is also regrettably the case that some providers have seen distance education as a cheap and easy route to income generation and have mounted courses of questionable value. Steps commonly taken to ensure quality by more reputable providers include some or all of the following.

Good initial design, informed by detailed subject knowledge, sound pedagogy, and an awareness of modern educational technology.

Incremental improvement cycles for materials and systems, typically based on a sequence of steps such as: produce, use, evaluate, improve.

A team based approach to the production and learning and assessment materials, involving a mix of specialists and calling on them to constructively criticise the work of other team members.

Distance education may be carried out on a range of scales but, as Sir John Daniel argued in his 1996 book Mega Universities and Knowledge Media [1], the pressures associated with cost and access have led to the development of more than a dozen institutions with more than 100 000 students that teach, in whole or in part, by means of distance education. Not all of these teach physics, but one that certainly does is my own institution, the UK Open University (OU). Here are some of the facts and figures that relate to the OU.

Founded in 1969, to teach at a distance and to operate an open access policy, it is now the UK's largest university with about 200 000 students (including postgraduates) registered each year.
Most of the students are UK based, but there are about 10000 students based in continental Europe each year, and an increasing number of students in other parts of the world.
The students are very diverse, but a fairly typical student is about 30 years of age, has a family and a full-time job. Most students study part-time while continuing in full-time employment. Students typically take 6-8 years to complete a Bachelors degree at a total cost of about 6500 dollars in course fees.

Several of these students are taking degrees by distance learning for career related reasons, but there are also many who are doing so purely for reasons of interest or as part of a lifelong learning agenda. About 25% of the undergraduates already hold a qualification from another university when they join the OU.

In the case of the Open University, the majority of the 3000 or so full-time staff are based at the University's headquarters in Milton Keynes. This is where the research laboratories and full-time postgraduate students are based. It is also where most of the undergraduate course production takes place. That is to say it is where courses are planned, where many of the purpose written textbooks, assignments and exam papers are produced, and where specialist software designers create the multimedia teaching packages that the OU distributes to its students. In addition, there is also a network of 13 regional offices distributed around the UK. These regional centres are responsible for recruiting, training and managing the 7000 members of the part-time staff (many of them full-time employees of other universities) who act as course tutors, providing the few hours of face-to-face tuition given to most OU students and marking their assignments. The regional offices also play an important part in making and maintaining the relationships between the OU and conventional universities that allow the OU to mount its annual programme of week-long residential schools that give the students the opportunity to carry out laboratory work and to develop the skills of group working.

Of course, not all distance teaching institutions operate in the same manner as the OU. The OU is a dedicated distance teaching institution, but in many cases distance education is simply an additional activity managed within a conventional university. In such cases it is common for conventional text-books to be used, possibly supported by purpose written study notes that serve in place of a lecturer's comments. Many providers of distance education use their own laboratory facilities rather than hiring them from other institutions, and few have access to the national broadcasting or software production facilities of the OU.

I the book referred to earlier, John Daniel estimated that the cost savings for large distance education institutions are between 20% and 80%, depending on the nature of the spend and the extent to which resources can be shared with conventional institutions. Overall, training a graduate by ‘complementary’ distance education costs about 50% of a conventional training in the same country.

THE PARTICULAR CHALLENGES OF PHYSICS

Any form of distance teaching produces a number of challenges. In some cases these may simply be specialized versions of the challenges that are inherent in conventional education. Others are particular to distance education, and some, of course, are specific to physics distance education. These challenges include the following:

1 Dealing with the hierarchical nature of physics knowledge, including the need for increasingly sophisticated mathematics as studies progress

2 Developing an appropriate range of student skills. (The skills involved with group working and oral communications present particular challenges and opportunities in distance education)

3 Providing adequate and appropriate practical work, in order to properly develop experimental and investigative skills.

4 Providing students with an appropriate level of learning support, academic feedback and advice concerning courses and careers.

5 Maintaining an examinations and assessment system that is appropriate to the courses taught and the qualifications offered, and which includes a rigorous system for identifying students who may be unknown to those who invigilate the exams.

Below are some of the responses to these challenges. Some are obvious others had to be carefully developed during the evolution of distance education. Almost all have been described as ‘impossible’ or ‘impractical’ at some time or another, but they are now well established as practicable and realistic. (For an account of the development of some of these responses see Open Science by Shelagh Ross and Eileen Scanlon [2].)

Dealing with a hierarchical subject. This is achieved by careful programme and module design, combined with the provision of clear study routes with defined patterns of pre-requisites. A typical ‘level’ structure, similar to that widely used in conventional undergraduate education might look like this:

Level 1	Introductory modules and short courses
Level 2	Broad survey courses
Level 3	Specialist modules
Level 3/4	Project work

The nature of such a programme is fairly obvious, but in distance education it is often the case that such programmes are studied part-time (and hence over an extended period) or in an open learning mode that reduces the formal prerequisites. In these situations there is likely to be an increased need for revision and review materials, and it may be necessary to integrate much of the mathematics teaching into the science teaching rather than treating it as an ancillary subject.

The learning materials themselves must, of course, be carefully considered. For those courses based on an existing textbook this may come down to a careful selection of the kind routinely carried out in conventional teaching. In other situations it may involve the production of purpose written texts, the selection and/or production of integrated media (CDs, DVD, etc.), and the deployment of additional support materials such as course guides, glossaries and handbooks. If a textbook is used, then it might even be appropriate to provide a purpose written guide to the text that enhances it in various ways, or at least provides extended solutions to some of the problems and exercises contained in the book.

Needless to say, the production of high quality teaching materials is expensive and time consuming, so this is not a task to be undertaken lightly or with inadequate support. To give an example, the Open University's second level 'survey' course, S207 The Physical World (Lambourne et al [3], and the Physical world web site [4]), occupies 32 weeks of part -time study at 12 hours per week and represents about 15% of the work required to obtain a BSc degree. The course has been purpose produced by a team of academics, editors, artists, designers and software developers, aided by secretaries, librarians and other support staff. The course comprises:

8 richly illustrated books (totalling approximately 1600 pages), printed in colour and co-published with the Institute of Physics Press
4 supplements (glossary, maths handbook, computer guide, specimen exam with solutions)
3 CD-ROMs with interactive Computer Based Learning packages
8 thirty-minute video programmes on DVD
8 hours of group tutorials provided in regional centres across the UK
1 computer marked assignment (CMA)
7 tutor marked assignments (TMA)
1 final exam, made available to students through a network of invigilated examination centres

Learning materials may sent through the post to the homes of individual students or made available over the internet. Each student is assigned to a local tutor who provides the (modest) face-to-face support for the course, answers questions by phone or e-mail and marks the TMAs. Each student also has access to course specific 'First Class' computer conference, and there is a course web-site with course news and updates.

Developing student skills. The issues involved in skill development have been widely discussed in the educational literature. Many physicists hope that such skills will emerge naturally from a traditional physics course. However, in the case of The Physical World, the final chapter of each book explicitly reviews and consolidates an aspect of skill development.

Book 2: Maths and IT activities
Book 3: Problem solving (prepare, work, check)
Book 4: Expository writing
Book 5: Critical reading/writing
Book 6: Using information sources
Book 8: Revision and exam skills

Practical work. Many providers of distance education are currently working to develop remote experiments that students can perform in real-time using the internet [5]. Others are developing various kinds of virtual equipment or even virtual laboratories as described in Paul Hatherly's article in this book. More traditional ways of building students' practical skills include the provision of robust kits of equipment (together with full instructions) that can be sent to students' homes. However, in this crucially important area it is hard to get away from the need to bring students together in a traditional laboratory where large items of equipment (possibly with complicated safety requirements) can be operated, and laboratory skills enhanced.

The Open University uses a variety of techniques to cultivate experimental skills, but most of its provision is located in dedicated practical modules such as SXR355 Quantum Mechanics; experiments, applications and simulations and SXR359 Electromagnetism; experiments, applications and simulations. Each requires 100 hours of work, is based on a purpose written textbook, and includes attendance at an intensive week-long summer residential school held at a conventional university. Each represents about 3% of the work required for a BSc degree.

Student support & feedback. Support and feedback may be provided in various ways. It can be based on communications technology, particularly through internet mediated conferencing and e-mail, though more traditional tools such as the telephone and video-conferencing also have their place. In the case of the Open University some support is provided face-to-face by part-time course tutors in local study centres all across the country. This is a complex and expensive part of the University's operation.

Exams and assessment. Assessments keep students on schedule and ensure an appropriate depth of study. Computer marked assignments (usually multiple choice) may be used summatively or formatively. Such assignments are simple to mark but costly in terms of setting time if they are properly constructed and truly probing. Also, their true educational value has been widely debated for many years despite extensive research. Tutor marked assignments enjoy a greater degree of respect and have the advantage of allowing great flexibility in a subject that can be mathematically dense and which often requires the use of technically precise graphics (e.g. graphs with axes labelled in accordance with SI conventions) but they are more difficult to handle at a distance and more expensive to mark. At the OU, the majority of maths and physics tutor marked assignments are still handwritten by the students and sent through the conventional postal system for hand marking and commenting by the tutor. Increasingly though, students are submitting assignments electronically (using scanned images of handwritten work where necessary) and tutors are using the electronic 'inking' facilities on tablet PCs to perform marking in a way that closely resembles conventional paper-based marking.

Exams present a major problem, they may be dropped for non-degree programmes, otherwise they may be taken on-line or handwritten at local examination centres. In either case steps must be taken to ensure that the person taking the exam really is the registered student. Providers of distance education are dealing with this problem in a variety of ways. Some are using the networks of 'testing centres' maintained by third party operators but at least one is using an on-line system that includes webcam invigilation and finger print recognition.

SOME UNEXPECTED BENEFITS AND OPPORTUNITIES

The large growth in distance education of all kinds over recent decades is, of course, attributable to the many opportunities that it has been able to exploit. A good example is the growth of in-service courses for physics teachers. There are several such courses in the USA, often combing an element of distance education with a summer residential school. A quite different example is the FiPS course, covering the first two semesters of a physics major course, provided by the University of Kaiserslautern, in Germany, for those performing compulsory military service who wish to subsequently study physics. In such cases the work being done by the students is of such a nature, or so located, that their employers do not wish to release them for training in a conventional university, even though university-level training or updating is desirable. Distance education is the obvious solution though it may sometimes be difficult to find the critical number of students needed to make distance education cost effective. For this reason, distance education is often best conducted through alliances, or in collaboration with other universities.

Some possible areas for collaboration include:

course design and the creation of teaching and assessment materials
special educational projects to meet regional or national needs
mutual support in the face of declining student numbers

Some of the physics distance education projects designed for the training and/or support of teachers are described in the Proceedings of the 2003 GIREP International Seminar [6] which are devoted to issues of quality in the preparation of teachers. The projects describe there cover the full range from on-line courses and electronic educational portals to national support efforts, such as the Open University's text-based 'Physics for Science Teachers' and the more recent Institute of Physics initiative 'Supporting Physics Teaching 11-14' which uses materials (produced by a team of teachers and academics) that are distributed on CD-ROMs. Many of these projects would not have been possible at all were it not for the willingness to build partnerships and develop educational alliances.

Since, by their nature, distance education courses are 'transportable' from one institution to another, and since they often involve the development of expensive (copyrighted) teaching resources, it is relatively straightforward to develop arrangements whereby expertise or services provided by one university can be exchanged for materials or methodologies developed elsewhere within a distance education programme. This particular aspect of physics based distance education may well be of increasing significance in the future if the decline in physics enrolments observed in many countries continues.

Amongst the many projects that illustrate the potential for collaboration in distance education the largest, most recent and most exciting in my personal experience is piCETL, the Physics Innovations Centre for Excellence in Teaching and Learning [7]. This is part of a 570 million dollar initiative by the Higher Education Funding Council for England (HEFCE) that has established 74 Centres for Excellence in Teaching and Learning [8]. The Open University is the home to four of these centres, the maximum number allowed under HEFCE's rules. The award of a CETL recognizes the excellence of past achievement and the potential to further develop that excellence and disseminate it across the relevant sector.

Some of the centres are subject oriented, such as the Physics Innovations CETL, while others are directed more towards teaching methods, student support or assessment techniques. The centres are expected to have a direct and substantial impact on the learning experiences of a large number of students, they are also expected to raise the profile of excellent teaching, and promote reflective evidence-based teaching.

Many of the 74 CETLs may have some impact on the teaching and learning of physics and astronomy, but only piCETL is entirely devoted to physics. In common with about 30% of the CERLs the Physics Innovations CETL is the result of a collaborative bid, led by the Open University in partnership with the University of Leicester and the University of Reading. The partnership is built on existing expertise in multimedia teaching, problem-based learning and skills-based laboratory teaching, and is further developing these approaches through joint projects that will eventually benefit a very large number of physics students. For further information about the CETLs see the HEFCE web-site http://www.hefce.ac.uk, www.hefce.ac.uk and look under Learning &Teaching/CETL.

CONCLUSIONS

Distance education in physics (and astronomy) confronts teachers and educational administrators with a range of significant challenges. However there are strong motivations to overcome those challenges and working examples of how to do so based on decades of experience. Distance education is now a well established mode of university level physics teaching that has demonstrated its ability to survive under challenging circumstances that have led to the closure of several conventional physics departments. Distance education has particular strengths in providing mature students with a ‘second chance’ for university education and in allowing lifelong learning without disrupting flourishing careers. It can also provide a cost effective alternative to a conventional physics education in circumstance where issues of cost or access restrict the availability of places in conventional institutions, especially when working in partnership with a conventional university system.

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