Teaching and learning physics at a distance

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Abstract

This paper provides a broad overview of physics teaching and learning by means of distance education. It considers the features, methods and motivations that characterize this particular approach and explores some of the challenges and opportunities that arise. Several examples are quoted, particularly from the UK Open University.

Characterising distance education

A simple definition of distance education, derived from the more extensive and precise characterization provided by Keegan (1990), describes distance education as follows.

Education in which there is a quasi-permanent separation between students and their teachers throughout the educative process.

From the point of view of both the providers and the consumers of distance education, the teachers and the learners, an important adjunct to this is that the teaching activity is generally separated, in time and/or space, from the learning activity

It is also common for there to be further separations. For instance, learners are quite likely to be quasi-permanently separated from other learners, and from key resources such as libraries and laboratories. Many of the characteristic features of particular implementations of distance education are designed to overcame these or similar separations (see Ross (1995) for a full discussion). Amongst those characteristic features are the following

- carefully designed learning and assessment materials.
- use of 'blended' media; including print, TV, radio, CD, DVD, WWW etc.
- greatly reduced 'contact' hours compared with conventional education
- some student support (tuition, marking, course selection advice etc.).
- flexible study patterns, possibly part-time.

Another feature of distance education identified by Keegan is the centrality of the educational institution responsible for providing the distance education. Because the teaching and assessment materials are generally produced by some 'distant' group of teachers, it is the institution that is generally seen as responsible for

- planning, producing and distributing materials.
- providing and coordinating student support.
- assessing learning.
- guaranteeing the quality of processes and outcomes.

Of course, these are usually *formally* the responsibilities of educational institutions, particularly universities, but in many conventional institutes the real responsibility is delegated back to the teachers. However, this is unlikely to be the case in distance education since the teachers may have retired, moved elsewhere or simply gone on to other projects while their learning and assessment materials are still being used by students. In some cases this shift in responsibility can leave the student with the feeling that they are being taught by the institution rather than the teacher! This may or may not be welcomed by the student.

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. Common steps taken to ensure quality by more responsible providers include some or all of the following

- Good initial design, informed by detailed subject knowledge, sound pedagogy, a good awareness educational technology and good sense
- 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 learning may be provided in a *synchronous mode* that requires students to be involved at some prescribed time (in order to participate in a telephone conference or an on-line tutorial for instance). It may also be provided in an *asynchronous mode* that 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 had.

Motivations for distance education

There are many reasons for wanting to teach at a distance apart from the crassly commercial. The most important concern student needs, in particular the needs of students who are prevented from regularly attending a conventional university by factors such as:

- work and/or family commitments
- homes or jobs in remote locations
- physical disabilities

The possibility of teaching in an asynchronous way makes distance education especially suitable for those with the commitments that typically come with maturity, and thus renders it particularly appropriate for lifelong learners, and for those who simply want a 'second chance' to benefit from a period of formal education. However there are also other motivations for wanting to teach at a distance, motivations that have more to do with politics and economics rather than education. Here are three:

1 The removal of some of the constrains of conventional university education enables distance education to play a distinctive role in promoting inclusivity and social justice.

2 Where distance education is carried out in a way that complements conventional education, the sharing of staff and facilities (laboratories for example) can increase the overall efficiency of a national higher education system to the benefit of all concerned, including taxpayers.

3 Where distance education is carried out on a large scale, the sums available for the development of distance teaching materials can be very substantial. These large sums can be used to produce expensive resources, such as professionally designed and developed educational software, that might be beyond the means of any single conventional university. In this case the motivation for distance education might have more to do with the ambitions of the teacher than the needs of the student.

A final group of motivations for distance education arises from 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 since then. For a private university, the figure is much higher and it too has been growing. In the UK the growth in higher education is causing governments to increasingly shift the cost of higher education from the state to the individual. Elsewhere in the world, particularly in developing countries, population growth coupled with increasing educational expectations is producing an enormous demand for university access. For these and similar reasons, the development of distance education can provide a cost effective alternative to traditional university education that eases the problem of access, provided the appropriate communications infrastructure is available.

Settings for distance education

In his book Mega Universities and Knowledge Media, (Daniel (1996)), Sir John Daniel, a former Vice-Chancellor of the Open University has analysed the pressures associated with cost and access and related them to the development of mega-universities – institutions with more than 100 000 students that teach, in whole or in part, by means of distance education. Here is an updated list of those institutions.

Bangladesh	Bangladesh Open University,
China	China Central Radio and TV University,
France	Centre National d'Enseignement à Distance – CNED,
India	Indira Gandhi National Open University,
Indonesia	Indonesian Open Learning University,
Iran	Payame Noor University,
Pakistan	Allama Iqbal Open University,
South Africa	University of South Africa,
South Korea	Korea National Open University,
Spain	Universidad Nacional de Educación a Distancia – UNED,
Thailand	Sukhothai Thammathirat Open University,
Turkey	Anadolu University (Anadolu üniversitesi),
UK	Open University – OU,

Not all of these institutions teach physics at a distance, but some do and their contribution can be significant. (Some, after all, have more than half a million students.) As an example, here are some of the facts and figures that relate to the UK Open University.

- 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 now about 5000 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 of age, has a family and a full-time job. Most students study part-time while continuing in full-time work. Students typically take 6-8 years to complete a Bachelors degree at a total cost of about 6000 euros in course fees.
- Each year about 6000 students embark on science studies at the OU, about 500 take introductory physics, and about 600 take introductory astronomy (there is some overlap between these two groups.)

The last of these points should be seen in the specific context of UK higher education, where about 3000 students per year embark on physics courses in conventional universities. (The accurate number is somewhat less and is gradually declining year by year.)

Of course, the teaching of physics (and astronomy) at a distance is not limited to the Open University and other mega universities. Distance education provides an important complement to conventional education in an increasing number of institutions. These institutions are very diverse, but it is interesting to identify common trends or features that pick out particular groups. One such feature concerns the provision of in-service training for teachers. Many institutions, particularly in the USA, now update physics teachers via distance education; some 'dual-mode institutions' provide this kind of teaching alongside more conventional courses for those who are able to study on campus.

Whether in dual-mode institutions or in mega universities working in cooperation with a national network of conventional universities, distance education can lead to cost savings and economies of scale by sharing a range of facilities and resources, particularly:

- academic and support staff
- labs and lecture rooms
- student accommodation
- catering, cleaning etc.

In the context of the UK Open University, about 50% of the national network of course tutors who help support the distance teaching of students are also employees (often full-time) of other universities. Many of the tutorials they present take place in teaching rooms that have been hired from conventional universities in evening or at weekends. Similarly, much of the experimental work that is such an important ingredient of any physics degree is taught in intensive week-long residential schools that use labs, residences and catering facilities that have been hired from conventional universities all across the UK. To make this possible the residential schools are normally held in the summer, when conventional universities are not using their labs. To accommodate this pattern of working, the Open University has adopted an academic year that matches the January to December civil year.

John Daniel estimates 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 is about 50% cheaper than a conventional training in the same country.

Teaching physics at a distance: challenges and responses

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.

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 ¾ 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 rather than treating it as an ancillary subject.

The learning materials themselves must, of course, be carefully designed. For those courses based on an existing textbook this comes 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 careful 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 provided by 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 UK Open University's second level 'survey' course, S207 The Physical World (Lambourne et al (2000)), 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 CBL 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

Materials are sent through the post to the homes of individual students, typically in two or three separate mailings. 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 nrws 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 Problem solving (use of diagrams)
Book 7 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. Others are developing various kinds of virtual equipment or even virtual laboratories as described elsewhere in these proceedings. 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 UK 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 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 the University of Sussex. Each represents about 3% of 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 UK Open University some support is provided face-to-face by part-time course tutors (often full-time employees of other universities) in local study centres all across the country. This is a complex and expensive part of the University's operation, largely organized by permanent staff based in the University's thirteen regional offices.

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. Tutor marked assignments are more likely to be used formatively, but 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). Exams present a major problem, they may be dropped for non-degree programmes, otherwise they may be taken on-line or at local centres. In either case steps must be taken to ensure that the person taking the exam really is the registered student.

Teaching physics at a distance: opportunities and alliances

The large growth in distance education of all kinds over the past several decades is, of course, attributable to the many opportunities that it has been able to exploit. The development of in-service courses for physics teachers is one example that has already been noted. Other groups that have been supported by physics related distance education include serving members of the armed forces and various groups of health workers (e.g. radiologists). In all cases the work being done by these potential 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 essential. Distance education is the obvious solution in such cases, though it may sometimes be difficult to find the critical number of students needed to make distance education cost effective in such situations. 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 (in press), 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 (e.g. the Telmae portal, which is also described elsewhere in these proceedings) 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 its very 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 continues. Physicist must surely hang together if they are not to hang separately.

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