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Learning and Teaching Support Network

LTSN Physical Sciences Practice Guide

Designing Independent Learning Material for the Physical Sciences

Stuart W. Bennett

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Preface

What follows are brief, personal ideas about the creation of independent learning materials in science. They have their basis in research, in years of producing materials and in the views of the students who use them. In no way are these ideas intended to be prescriptive or comprehensive: indeed, there is no single right way to produce independent learning materials. What has priority is that the material is designed with due regard to financial, facility, time and human resource implications and the nature and social and cultural background of the student body.

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A Perspective

In retrospect, the single, distinguishing feature of higher education in the United Kingdom in the last decade of the 20th century has been the huge increase in student numbers. The opening up, access to and the expectation of higher education by an ever-increasing student market is a feature not just of the United Kingdom, nor of Europe, but of most of the World. The proportionate increase in resources to meet the demand has not appeared. Teachers have rapidly realised that traditional methods of teaching and learning cannot cope with the changing profile and increasing size of the student body.

A parallel viewpoint from employers and students is the expectation that higher education should provide a basis for successful employment. No longer would the 'knowledge' gained in higher education be adequate for a changing employment environment. Students must develop the means to learn and be able to apply learning skills throughout their working lives. The need for higher education to foster an ethos of independent learning has never been higher. One could argue that this need has always been catered for (at least to some extent) in undergraduate courses. However, science has not been near the vanguard of such a movement. Teacher/student contact hours have always been high in science (many lectures, tutorials and practical classes), an approach predicated by the belief that there are lots of facts and skills that have to compiled before the student can make any significant creative input. A comparison with teaching of the arts is salutary. Contact hours are fewer and the students spend proportionately much more time in extracting and selecting information, in constructing arguments and in discussion and development of viewpoints. As a result, a new arts graduate is probably stronger in transferable learning skills than is the science graduate. Perhaps we have much to learn from our colleagues in the arts and social sciences.

The skills of independent learning take time to develop. It is of little value transcribing lecture notes, adding a reference text and throwing this at the incoming undergraduate. Materials for independent learning have to be designed and structured in a way that maximises the students' opportunity for success, although many of the factors that are important here are just as important in the design of more conventional learning programmes. By its very nature as a distance education institution, the Open University has always operated in a culture of independent learning. Over the years we have made mistakes but have also achieved success. In the following pages, I hope to be able to outline some of the features that have proved to be successful in the design of our own independent learning materials.

Where do we start?

The two vital features of the design of a learning programme are the starting point and the finishing point: what do the students know and what they can do at the beginning of the programme and what do they know and what can they do at the end of the programme. There is perhaps an analogy here with thermodynamics where 'success' is judged only by the starting and finishing points and not the route between. As teachers we additionally have a responsibility for the route and the choice of route can be an important factor in reaching the destination for some students. In this section we shall focus on the starting point.

A consequence of a greater proportion of the population entering higher education has been a decrease in the homogeneity of the student cohort. No longer is it valid to assume that all new undergraduate students will arrive with similar educational experiences and achievements. The changing age profile of the cohort results in a range of experiences and skills. Is it not perhaps unreasonable to assume that a rigid teaching framework will fit all students?

An activity that is central to commercial marketing is to profile potential customers. Perhaps this has not been necessary in higher education before but, like it or not, we are now operating in a market with a product, a price and with competitors. Knowledge of our customers can help us to attract and retain them by informing the structuring of our materials.

To try to give this booklet some reality and to avoid constant generalisation, I am going to illustrate some features of independent learning materials with an introductory chemistry module that we designed at the Open University (*ST240 Our chemical environment*). The module represents 30 credit points (in the context of a 360 credit point BSc) or 300 student activity hours. We assumed some limited transferable learning skills (extracting relevant information, summarising articles, formulating an argument etc) but no specific chemical 'knowledge'. The aims were that the module should be accessible to a wide range of students by using contexts which:

- Have some familiarity to the students
- Attract, interest, engage and retain large numbers of students
- Provide a departure point for students going on to other chemistry-based modules but would represent a terminal chemistry module for students progressing to other areas.

This represents the 'challenge' definition, the first part of the production process depicted in Figure 1.

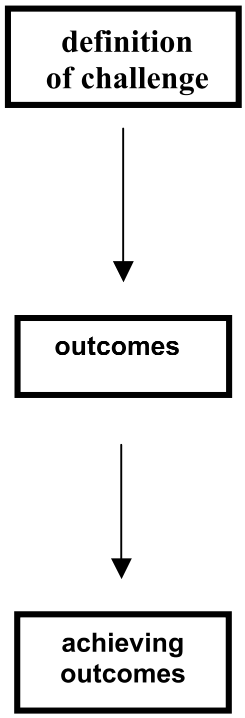

Figure 1. Route for creating independent learning material.

The first step is to turn our attention to potential students. These people are the consumers but what do we really know about them? It could be argued that the Open University student body is at least as inhomogeneous as that at any conventional university. There are no formal entry requirements based on educational qualifications, students span a large age, employment and ability range and come from all walks of life. However, this difference between the Open University and other higher education institutions in this respect is decreasing year on year. The results of a survey of potential (and, as it happened, actual) students gave us the information shown in Figure 2.

The main reason for profiling the student body is to try to design the material so that it takes into account the range of student backgrounds. Students have different learning styles. Some learn better from simply reading material, others through working on tasks and assignments, and others through peer group interaction (either directly or by more remote communication) and so on. Additionally students bring 'baggage' with them that affects the way that they learn. Learning is an active process and students' past experiences will affect the way that they construct their learning. Profiling too (perhaps via diagnostic tests) helps define the skills and the knowledge of the student body that can be assumed, i.e. the entry behaviour. Any shortcomings can be pinpointed and individual students directed to bridging or preparatory material in good time.

Often the independent student is a mature person who is trying to fit studies into a busy programme which may include work and family commitments. Motivation to study may be tempered by other demands on the students' time. Perhaps more importantly, the independent student tends to study in relative isolation with limited peer group contact and this can lead to a sense of isolation. What can independent learning material do to address these problems?

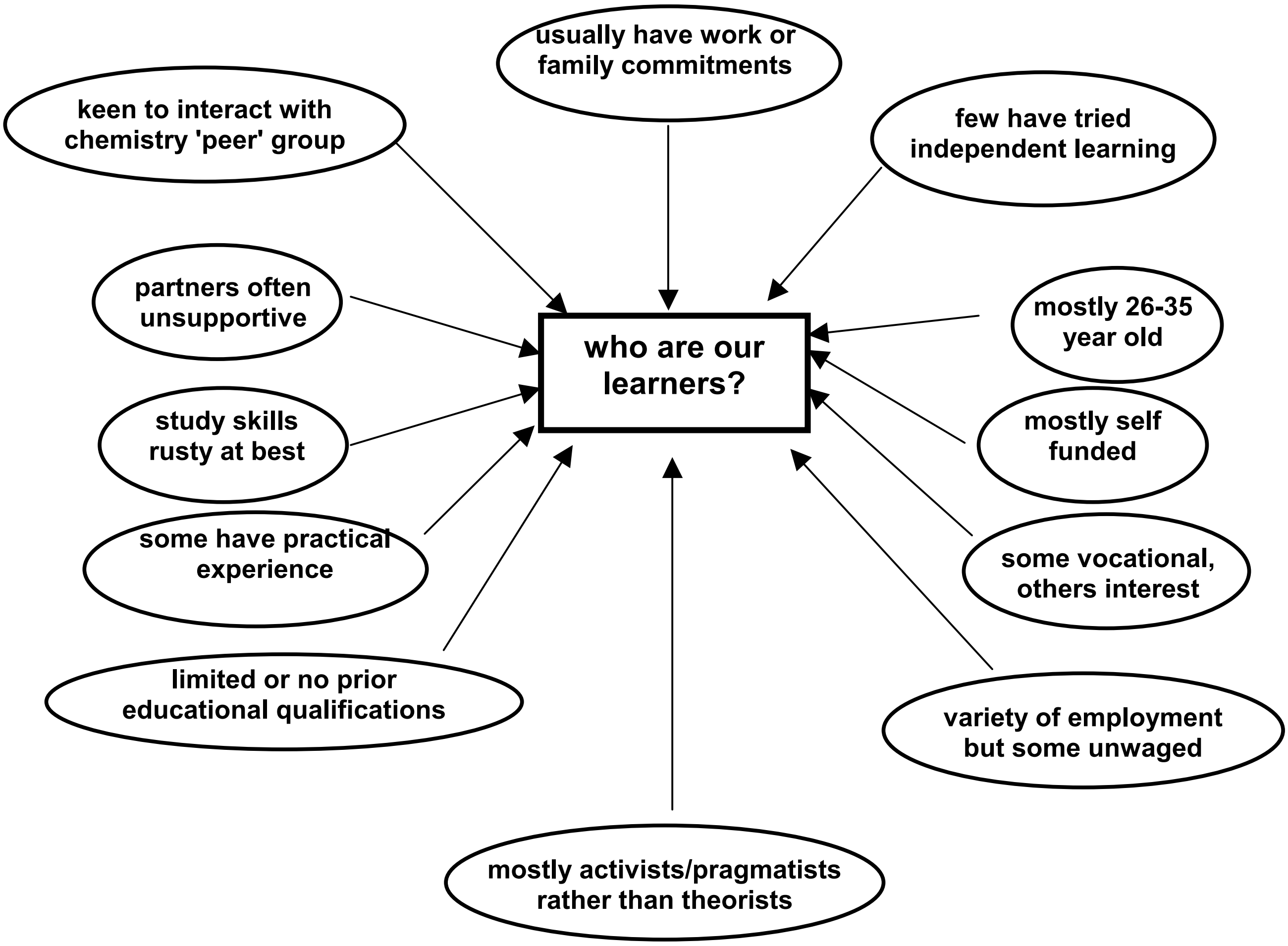

Figure 2 Student profile for incoming students to *Our chemical environment*

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relative isolation with limited peer group contact and this can lead to a sense of isolation. What can independent learning material do to address these problems?

Through its design it should:

- Inspire and motivate the student (possibly through contextualization)
- Build confidence by letting the students assess for themselves just how much they really know
- Be student-friendly and interactive
- Be sympathetic to the cultural, social, economic and gender mores of the student body.

What is the destination?

There are essentially two ways of approaching the design of a new course or module. The first way is to decide what should be in the module; what topics should be included. This is a common approach and is often predicated by the needs of a following module in the sense of student entry preparation. The great danger here is one of information overload.

Teachers of physical sciences are outstandingly successful at introducing undergraduate students to new ideas, to new research and to new information. In the space of a very few years, an area can go from being at the forefront of research to featuring in every physical sciences undergraduate programme. (The chemistry of the Buckminster fullerenes is an obvious example.) However, we are rather poor at removing existing material. Our expectation of the capacity of students to absorb ever-increasing quantities of information is greatly misplaced. An illustration of this tendency can be seen in the brief comparison of two classic inorganic chemistry texts: *Advanced inorganic chemistry* by F A Cotton and G Wilkinson (Wiley, 5th edition 1988) and *Textbook of inorganic chemistry* by J R Partington (Macmillan, 5th edition 1943). Cotton and Wilkinson exceeds Partington in number of pages (by a factor of 1.40), in total page area (x 2.36), in index entries (x 2.46) and even in mass (x 2.05). The situation has become even more extreme as we enter the 21st century.

An alternative approach is initially to ignore content. Ask what the student should be able to *do* at the end of the module, focus on outcomes and, more specifically, on objectives. There is fashion in all branches of learning, and educational theory is no exception. In the 1970s, the behavioural objective represented a buzz term and no self-respecting teaching document would appear without a comprehensive list of objectives. As the decade progressed, the behavioural objective was seen to be unnecessarily restrictive in that, in isolation, it appeared to limit creativity and the development of those skills that are not easily defined and quantified. Courses appeared with a set of general aims, which although useful, did not identify the outcomes of the course with much precision. Since then, there have been changes in terminology and for some time 'goals and outcomes' has been an expression that has enjoyed popularity. In distance education, the behavioural objective remains of major importance. It is an aid both to the student and to the teacher.

Objectives can assist teachers in:

- The design of a course
- Deciding on the contents
- Sequencing the contents
- Selecting the teaching media
- Designing learning activities
- Developing assessment material
- Evaluating the course.

Objectives can assist learners in:

- Deciding whether a course suits their needs
- Knowing what will be demanded of them
- Focusing on key areas of teaching
- Planning of study time
- Checking developing competence
- Measuring progress
- Reviewing work on the programme.

So how do we begin designing objectives? One useful approach is to ask a series of questions that you would want students to be able to answer by the end of the module. One of our requirements for our module was that students should start from familiar experiences so the set of questions necessarily had this focus. The emphasis was on the immediate environment of the student.

- Why did the Bronze Age come before the Iron Age?
- Why do oil and water not mix (except that they do in mayonnaise)?
- Why do some dyes not work well on certain fabrics?
- Why is the colour of hydrangeas dependent on where they are grown?

For a different module, it would be equally valid to ask questions that were intrinsic to the study of physical sciences as a discipline. However, it is essential to keep an emphasis on outcomes rather than content in the selection of questions.

Over the last decade, many face-to-face and distance learning institutions have moved towards modular programmes. The need for well-defined objectives that accurately delineate competencies is paramount for a student who is attempting to assemble a programme of learning. Programme outcomes inform module objectives. However, these objectives are also essential for teachers who increasingly work in teams to produce modules. For example, two teachers may agree that one outcome of a course is that the student should 'know how to use graphs'. There is a big difference between the plotting of data to give a straight line and interpreting a three-dimensional probability function based on polar co-ordinates. Exactly what is it that the student should be able to do? Members of a team must be clear about what each of them understands by a particular competency and a defined behavioural objective is an effective way of achieving this.

Our idea of examining what the student should be able to do is emphasised in the way that we phrase objectives. Terms used must ensure that the student knows what will be expected.

'Abstract and use relevant data (e.g. solubility, biological activity etc) to choose molecular characteristics that could be incorporated into the design of a compound to give it a particular property.'

This objective gives the student (and the teacher) a better idea of what the student might be expected to do than does the alternative phrasing.

'Understand how molecular characteristics effect the properties of compounds'.

There should, in general, be qualifications in objectives that help to confine scope. It is best to avoid terms such as 'know, understand, be familiar with, have a good grasp of, appreciate, believe', which give little direction. Better terms are 'state, explain, evaluate, outline, compare, apply, assess'.

It is when questions have been devised and objectives defined that the content of the module becomes apparent. Certainly there is a level of iteration required between content and objectives but in this (second) approach, content is not the driver. At this stage, it is worth looking at the skills that we wish students to develop. For our module, skills can be categorised under three main headings. Exemplars are shown in Table 1.

Skills category	**Example**
Chemical	Calculate quantities using chemical equations
	Represent 3 dimensional structures in two dimensions
	Predict chemical reactivity using functional group approach
Environmental	Predict effect on water treatment plant of increase in detergent use
	Account for decay of limestone buildings
	Identify advantages and disadvantages of green as a colour for plants
	Explain how red poppies and blue cornflowers can use the same pigment
Transferable	Evaluate data in support of a thesis
	Summarise a paper and make a 2 minute presentation
	Organise a team to investigate an environmental problem
	Construct and present an argument

Table 1. Classification of skills

The important feature is that skills cannot be developed in a quantised way, they have to be developed progressively throughout the module. Each skill can be broken down into components and tests devised for each component. A breakdown for ‘construct and present an argument’ is shown in Table 2.

Skill Component	Test
Scanning, speed reading	List points
Define criteria for relevant information	List criteria
Selecting relevant information	List information
Develop steps in argument	Write outline
Group information to support step	List information in groups
Construct argument	Devise logic route
Present argument	Two minute lecture, write article
Evaluation	Self/peer group

Table 2. Breakdown of 'Construct and present an argument'.

An example of a chemical skill is the representation of a three dimensional structure of molecules on a two dimensional page. So that the student is not overburdened, different representations are introduced progressively. There are many introductory situations where the ‘flying wedge’ or the Newman projection is an unnecessary complication. The basic idea of the 'Lego' brick is quite adequate right at the beginning of an introductory course and this can be followed by the 'ball and stick', the ‘symbol and stick', the 'contraction' (such as $CH_3CH_2CO_2H$), the 'skeletal' and the 'three dimensional flying wedge' styles. There is no need to have a separate section of the module on molecular representation. A new form can be introduced to run briefly alongside an existing form, which is then subsequently phased out.

How do we get there?

Having defined the 'challenge', taken a look at outcomes and objectives that define them and skills development, we can start on the process of design, i.e. *achieving* the outcomes.

In some respects a module for independent learning is not very different from a conventional face-to-face module. However, it is even more critical that the independent learning module enjoys good design as the delivery method necessarily implies that there is limited opportunity for amendment and for student query. To this end there is a strong argument for using a team approach rather than assigning the responsibility to an individual. It may seem that this is extravagant in use of resource but a high quality product is needed for the independent learner.

The team should be brought together right at the beginning of the design process, certainly before objectives are defined. There is no doubt that the collective approach can produce something that could not be done by the individual. At its best, it is a creative process not unlike the solving of a crossword that may be impossible for one person but two working together, feeding off one another, have a good chance of solving it. There is a criticism levelled at the team approach by sceptics in that it may produce a ‘camel’. This will only happen if compromise is made to members' hobbyhorses (to mix metaphors) rather than focusing on the student exit behaviour.

This not the place to go into the detailed structure of a team and the selection of members. However, the team does need to have individuals who *collectively* have a range of skills. Playing to individual strengths and ignoring weaknesses achieve success. Working on a team can be traumatic for some in that a person is exposed to peer group criticism in a way that the face-to-face teacher rarely is. It is essential therefore that each member is valued and that each member of the team has ownership of the project.

Once objectives and skills have been defined the next stage is to develop content. It is usually the case that content is uppermost in the educator's eye. It should not be overlooked that particular objectives can be achieved through a variety of material. For the *Our chemical environment* module, a 'content structure' evolved which focused on areas of interest, shown in Table 3.

Materials	Metals, ceramics, polymers
Energy	Sources, fuels, impact
Nutrition	Food types, synthesis, metabolism
Health	Cleaning (detergents), how drugs work, screening, drug design
Senses	Colour, smell
Futures	A cure for influenza, nanotechnology, smart materials

Table 3. Areas of interest for *Our chemical environment*.

Given that we were starting with 'chemically inexperienced students’, there were a number of traps that lay in wait. We had to *attract* the students' interest and then *retain* it. This meant writing material in way that perhaps bucked some of the conventions of formal physical sciences teaching. Learning from how articles are written in the 'popular' scientific press, from the literature of other disciplines and from colleagues in other disciplines proved to be a most valuable exercise.

It is useful (at this level) to ask the question 'Why does chemistry (or indeed any of the physical sciences) have limited popularity?' This should be asked not just of chemistry colleagues (who presumably think that chemistry is fascinating anyway), not just of chemistry students (who have chosen to study the subject for whatever reason) but also of students and potential students who are not studying chemistry. The outcome of such an exercise was to lead to a somewhat damning indictment of chemistry as perceived by many. We may argue that the picture that emerged was not fair but that is not the point: it is our responsibility to try to change (or at least alleviate) the basis for criticism.

Physical sciences are not seen to be dynamic or alive by the average university entrant. Basically, there is the need to learn lots of facts and abstract ideas then reproduce them in examinations. A comparison with the study of literature is informative. From the beginning, there is opportunity for opinion and discussion and skills of argument and interpretation are rapidly developed. To get to this stage in physical sciences takes years and not until the end of a undergraduate programme does the black and white image of the subject begin to recede. It is a long time to wait to have intellectual fun.

Physical sciences are difficult. There is a lot to learn and it is not just science. Mathematical skills can play a significant part and one needs a familiarity with a new language of terms, models and symbolism. We often assume all of this (often without giving the student time to develop these skills) and expect the appropriate skills to be brought into play when the learning focus is on a new chemical area. There is ample evidence to suggest that the apparent inability of some students to perform well is not due to their inability to deal with a particular concept or idea but due to the fact that they have been deflected by having to handle too many other things at the same time. A student who has failed to grasp the precise way in which we represent atoms and molecules is almost immediately in trouble. Is it reasonable for us to assume that all beginning students see S as a sulfur atom, N as a nitrogen atom but SN is a molecule and Sn an atom of a different element, tin? S_2 represents two sulfur atoms bonded together but 2S is two separate sulfur atoms. Or have we been talking about atoms and molecules or moles? We give no indication and then there is the not insignificant factor of around 6×10^{23} involved.

Students see long contact hours in studying physical sciences. In part this arises through the demands of practical work (whether or not so much laboratory time should be devoted to practical work is a question to be discussed elsewhere) but physical sciences students do have far more lectures than their colleagues in the arts areas.

The image of physical sciences is not good. Whilst the subject will inevitably be pilloried by the press for environmental problems such as the ozone hole, global warming, and industrial pollution, we do very little to help ourselves. How often do we counteract these pejorative images with emphasis on drug design, smart materials, non-polluting fuels and ways of improving the environment? These perceptions of physical sciences proved to be invaluable in balancing the content of and moderating the approach the intellectual design of the module.

In addition, we should ensure that:

- Student entry and exit behaviour for the course are clearly defined
- The material is absolutely error free and logical discontinuities are absent
- Concept maps are constructed to identify links and hierarchies
- Due regard is taken of *progressive* skills development
- Other courses that the student is likely to be studying in parallel are taken into account
- A spiral curriculum that revisits concepts is considered
- The number of new tasks, ideas or concepts that the student is expected to handle at one time is reasonable
- A *realistic* assessment of student study time is made.

Media

The selection of appropriate media is a critical part of the design process. There is a range of media available to the distance teacher: text, video, audio, home experiments, residential school, computing etc. Each one has its strengths and weaknesses and also its costs both in terms of material and human resource. The question that has to be answered is what medium is best able to deliver a particular concept or idea within resource constraints. The course package based on a range of such media can be termed *multiple*-media. The expression *multi*-media is reserved for computer-mediated packages which embody text, graphics, video and sound in an interactive environment. A multi-media component is now considered to be an essential part of a multiple-media package that may incorporate CDROM/DVD delivery.

A consequence of this package is that the student can be faced with a non-linear study pattern. There is little planning (on behalf of the student) required for a series of lectures supported by an 'adopted' text. When confronted by an array of media, the student can experience great difficulty with navigation. A route map must be developed which plots study progress.

In terms of study time for the distance student, hard copy text has been and probably will remain for some time, the most important medium. Reading text from a screen does not yet have the convenience of, nor is as friendly to the eye as, the printed word. It is here that we shall begin a brief survey of the media.

Text

Currently, this is the most important medium for the distance learner. Students are used to inputting information through the written word and, with diagrams and equations, this becomes a very flexible medium. It can also be accessed anywhere; no special facilities are required and the text can be easily annotated with notes by the student. For the independent learner, the text must be carefully designed. It has to be structured to aid the learning process, it must be interactive and it must be student friendly and attractive.

The student needs to be told just what they are about to study by way of an introduction. The teaching itself should have lots of examples and opportunity for reinforcement. Students should be asked to make their own summaries and compare them with summaries that embody the points considered important by the author.

Self-assessment questions should appear regularly and be linked to specific objectives. This represents the main way in which the student is able to assess whether they are meeting the standards and criteria set for the module. The link to objectives makes it possible for the student to focus revision and reinforcement.

All learning is predicated on previous experience. Whilst you may assume that recent material will be fresh in the student's mind, material from earlier in the module or from earlier modules will need to be cross referenced so that the student can access it if necessary. Within a piece of text you may wish the student to be referred to an experiment or video section. Make sure that this is signalled in advance and mark the appropriate spot with a suitable icon.

Style of writing can have a major effect on study. Keep to short sentences and use simple words where appropriate. Try to limit the concept density by introducing no more than one idea in a single paragraph. It is a good plan to apply a test to the text that will identify the worst excesses of convoluted writing. There are several so-called 'fog indices'. One that we have found to be useful is given by:

Fog index = 0.4 x (average number of words per sentence + percentage of words with more than two syllables)

A fog index with a value greater than 12 is an indicator that the text may be too difficult and complex.

Another check to make is with student workload. This is important not just in the context of a particular module but with the picture of other modules in the student's programme of study. Time needed to master particular skills will vary from one student to another but there is value in using a common currency.

As the text is the medium with which the student is likely to spend most time, it is here that the study-time assessment starts. Again, as with the fog index, there are several ways of doing this and most involve an assignment of text into one of three categories. Easy text represents prose that can be read and assimilated with a single pass. The difficult end of the scale is probably more appropriate to much physical sciences material and is text involving symbols, equations, complex ideas and a precision of language.

Each difficulty category is assigned a reading/study rate:

- Easy 100 words per minute
- Moderate 70 words per minute
- Difficult 40 words per minute

Time is then allowed for figures, diagrams, questions, activities, other media, assessment etc.

In addition to the main text, you may find a data book or glossary useful. Data books have a tremendous value in that they collect a range of data in one place. Identifying, selecting relevant data is a valuable skill to develop in the student and the data book ensures that all the students are using the same data when carrying out calculations. A glossary can aid the student with the jargon of science. If a term crops up, a simple glossary definition is often enough to jog the memory.

Text should be 'friendly' for the student. This does not mean that the style appears to be patronising. The use of 'we' rather than 'one' and sticking largely to active rather than passive use of verbs can help. Language should be kept simple. Seeded questions that cause the student to stop and think are useful in breaking up text, as are illustrations. The text should also be produced to the highest standards possible. Quality production seems to carry weight in our students' eyes.

Video

Both broadcast television and videocassette come under this heading. Access to cable or national networks, represents an opportunity for essentially free publicity for courses and programmes as well as representing a pacing device for the student.

If one can make the assumption that students have ready access to video players, the videocassette becomes a versatile medium. To make high quality video is relatively expensive but there are roles for which it is uniquely appropriate. Dynamic processes, creation of a three dimensional image by movement in two dimensions, experimentation including time lapse, expensive or potentially dangerous procedures, contextualization, authoritative speakers in a particular field are all possible. It should not be forgotten that video, an essentially linear medium, could be made interactive. Supply of data from an experiment can involve the student directly with the medium.

Audio

Audiocassettes are cheap to produce and the playing equipment is ubiquitous. A level of interactivity can be introduced if diagrams and illustrations to work from are included. Audio is particularly useful for discussing approaches to problem solving and argument construction.

Multimedia

The preceding two media are becoming less individually important with the penetration of multimedia computing into the student market. This medium offers not just the features of audio and video but genuine interactivity. Coupled with the resources of the Web and networked systems, multimedia systems offer an, as yet, barely exploited learning medium. However, no matter how powerful this medium may be, it does not represent the single ideal learning medium to the detriment of all others. It does have drawbacks.

On-screen text in large amounts is not easy on the eye and lacks some of the versatility of the printed page. However, the biggest problem is the teacher time required to produce good quality material. This has to be supplemented by professional designers to give the material a professional and userfriendly image. The computer has a significant to role to play in the area of data acquisition and database access in experimentation and has a valuable role in computer-mediated learning. Remote communication between tutor and student and between students is set to become a major teaching mode. Access issues are more restrictive than are other media. Nevertheless, computing and multi-media are becoming increasingly important in independent learning but their role should be treated to all the same critical rigour as other media.

Practical work

For any science course, one has to ask the question about the role of experimental work. For years, the view that one cannot study science without spending a long time in a laboratory has held sway. Often, not much account is taken of just what goes on in the laboratory and, in particular, how the laboratory activities contribute to the overall objectives of the programme. Experimental work will have a different role in each course and that role will depend greatly on whether the outcome of the programme is to produce practising scientists or to educate students in the logic, skills and culture of the pursuit of science.

Laboratory and fieldwork is expensive and it is essential that this time is used effectively in the context of a programme. Traditionally in distance learning, experimental skills have been developed through limited laboratory/field work access and the home experiment kit supplemented with the use of video. Use of cheap, mini-scale, disposable equipment can provide an economic and safe way to develop experimental skills, particularly for introductory courses.

The crux is to realise that many of the skills traditionally developed in a laboratory environment can be developed (to some extent) outside that environment. Multi-media methods have opened up a powerful route to the development of some of the skills of experimentation, particularly in the area of experiment design.

Assessment

A combination of course work and an end of course examination or thesis assess students of most independent learning courses. There are safeguards in this combination as it limits the possibilities of impropriety and provides a range of assessment modes that should not unduly disadvantage a particular student.

Student-produced work can be of a conventional written kind or be of a computer-marked nature. This latter has limitations but nevertheless is able to test a range of non-hierarchical objectives. Grading (and the supply of notes) is relatively inexpensive and can have a rapid turn around. The grading of written work is time intensive but higher learning objectives are easier to test by this method. Both modes of continuous assessment have an important teaching role and represent an opportunity for *individualised* feedback to the student.

The design of assessment material is often something of an afterthought rather than an integral part of the module construction. It hardly needs to be said that the assessment material should be linked directly to objectives or outcomes and checks should be made to ensure that all objectives are assessed and some are not over assessed. There is a tendency for assessment material to focus on those module objectives that are easy to assess and to ignore others.

Delivery, evaluation and quality assurance

There is little value in designing a course with care if the delivery system is flawed. Just how the students are to study the course is a vital factor to include in the initial planning process. The convenience and nature of back up is predicated by resource but must have regard for the material being studied, the location, circumstances and the time constraints of the student. There is no prescription here except to say that any good system seems to evolve from a close liaison with potential students and teachers.

Evaluation is probably the most neglected area of distance teaching. Checks have to be built into the design process, the individual course components and their collective whole, the delivery system, the assessment system and a system devised to 'close the loop' and enable action to be taken on findings. Further, one has to decide who are the appropriate people to be involved in these processes.

Overall, there is a parallel between producing a new course and a new chocolate bar. First research the market. Is there a demand for the course, what are the expected outcomes and how does it fit into existing offerings? The next step is to assemble the design team that should have some external input. At the Open University it has been the norm to have external assessors (from other universities) for each section of the course and at least one assessor to cover the course as a whole. Draft materials should be commented upon by all members of the design team and by student assessors. We have found that many changes that students have suggested have contributed greatly to the quality of the course.

One of the criticisms sometimes levelled (with some justification) at independent learning is that response to feedback is slow. So delivery of the course must be monitored by tutor and student questionnaire *and* provision made to act on the findings. Questionnaires have to be designed professionally so that responses to sets of questions suggest action. It is of little value to know that 30 per cent of students found a section difficult if there is no information on just why that section was found to be difficult. You will also need information on the quality of the material, time of delivery to the student, ease of access of the student to formal sessions etc. Another area that must be included relates to student performance. Although, this type of statistical indicator is often used to the exclusion of others, it is only of real use in a 'value added' context. The student input criteria have to be used as a baseline.

The point about quality assurance is that we need to be sure that we are doing what we think that we are doing. In other words, we must put in place criteria and checks that result in unequivocal evidence that we have achieved our objectives. We must complete the circle.

And finally.....

We have now reached the end of the design and production process. The inputs are summarised in Figure 3.

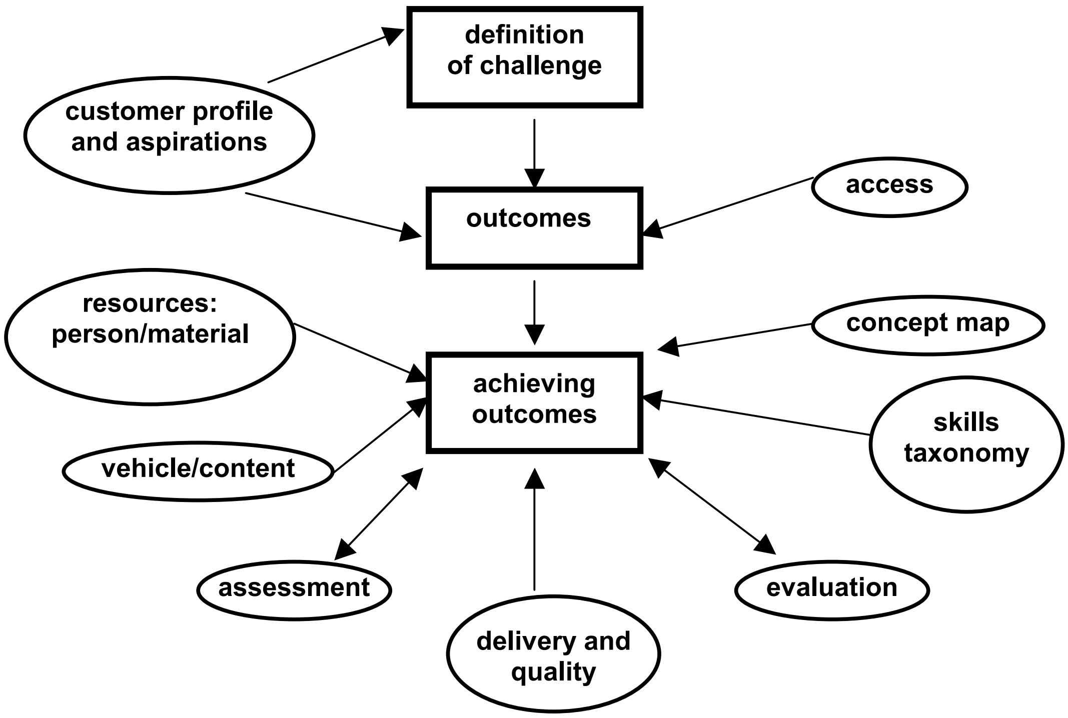

Figure 3. Inputs into independent learning material design

The design and production of quality distance learning material is an expensive and time-consuming process. Effort spent is never wasted and usually results in savings further down the line. Look at existing books and other materials; is it possible to incorporate such material into your design? Think about multi-use, flexible contextualization and access. Try to plan the totality of the course at the same time; the structure of the course, the individual components, assessment, evaluation, and above all, never lose sight of the view from the students' eyes.

Checklist
Market Resources Product design Product manufacture Product quality Advertising Delivery Evaluation and performance

Table 4. Checklist for creating independent learning materials

LTSN Physical Sciences Practice Guides are designed to provide practical advice and guidance on issues and topics related to teaching and learning in the physical sciences. Each guide focuses on a particular aspect of higher education and is written by an academic experienced in that field.

"Designing Independent Learning for the Physical Sciences" uses examples from existing Open University courses to indicate how effective independent learning material may be developed.

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