Title

Units 158-160 - Teaching Geographical Information Systems

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Unit 158 - Teaching Geographical Information Systems

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This unit was reviewed by Alan Jenkins, Oxford Brooks University, UK.

This section is not typical of the other sections of the curriculum in that it is primarily directed at instructors intending to use the *Core Curriculum* as a resource in their own curriculum design, rather than as materials to teach with. However, the materials might be used directly by instructors teaching the methodology of geographical education as part of an education elective within higher education. The materials draw heavily on standard educational literature, notably Brown G and M. Atkins (1988) *Effective Teaching in Higher Education* (London: Methuen & Co. Ltd.). Additional components related directly to teaching within a geography curriculum can be obtained from Gold, J.R. *et al.*, (1991) *Teaching Geography in Higher Education: a manual of good practice* (Oxford: Basil Blackwell Ltd.).

There are two units which together comprise the "Teaching GIS" section.

Units in this section

Types of GIS laboratory class
- Setting up the laboratory

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Unit 158 - Teaching GIS

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Unit 159 - Curriculum design for GIS

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This unit was reviewed by Alan Jenkins, Oxford Brookes University, Oxford, UK.

Advanced Organizer

Unit Topics and learning outcomes

- This unit outlines:
  - What is meant by the term curriculum and how it differs from a syllabus
  - Various curriculum design methodologies
  - The problems that GIS can create for curriculum design.
  - Educational motivations for using the laboratory method in teaching GIS
  - Problems in establishing GIS laboratories

Intended Learning Outcomes

- after completing this module, students should be able to:
  - define a curriculum as a system of inter-related parts
  - state why designing a curriculum solely by content is not always best practice
  - outline some formal approaches to curriculum design
  - list some of the problems to curriculum design posed by GIS
  - design a GIS curriculum for you and your students
  - justify the use of the laboratory class in a GIS curriculum
  - relate this use to the overall aims and objectives of the curriculum in which it is embedded
  - list and evaluate some of the published laboratory resources for teaching about and with GIS

  - outline the problems that will emerge in setting up a GIS laboratory and the necessary resources to overcome them

Instructor's Notes

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Metadata and Revision History

Unit 159 - Curriculum design for GIS

1. Introduction

- Defining and delivering an effective curriculum is THE most important professional responsibility for GIS instructors.
- GIS instructors in higher education have shown an almost exemplary concern for teaching. Concern for education in GIS goes back a long way (see Goodchild, 1985; Poiker, 1985).
- Concern and care for education in GIS has been a major factor in allowing the technology to diffuse so rapidly into geography and related sciences as well as into industry and commerce.

In attempting to design a curriculum, an instructor in GIS can turn to:

- Several published *examples of possible syllabuses* (Nyerges and Chrisman, 1989; Unwin *et al.*, 1990) The original *NCGIA Core Curriculum in GIS* (Kemp and Goodchild, 1992) was one of the most ambitious educational projects ever undertaken in geography in higher education. Unusually, it was subject to careful evaluation and assessment through individual case studies (Coulson and Waters, 1992) and overall user feedback (Kemp, 1992; Kemp and F.M. Goodchild, 1992). Nobody, least of all its originators, would claim it to be perfect, but it gave a 'kick start' to many educational developments. More recently, the methods used in the development of a European GIS curriculum in GIS and the resulting curriculum content, have been described by Kemp and Frank (1996).
- The *Proceedings of a number of international workshops* concerned with GIS education. Almost all of the major conferences include a `stream' relating to GIS education and training.
- The GIS community has produced many *general teaching resources*. Examples include a number of, low-cost, systems that run happily on basic hardware (see Fisher, 1989), some very useful vendor training products, 'general awareness' computer-based tutorial

systems, and some carefully designed packaged 'distance learning' materials making use of standard GIS (Langford, 1991). There are also a number of useful analogue videos (Hall & MacLennan, 1990).

- Increasingly, these materials are being made available to anyone who has access via WWW. A good place to start a search for these materials is:
  - the UK Computers in Teaching Initiative Centre for Geography, Geology and Meteorology site.
  - the NCGIA site or that at Edinburgh University in UK which list a very large
  - number of GIS related sites.

However, even with the benefits of these resources

- Many curriculum design issues remain unresolved.

- There is no single correct answer. GIS curricula will vary, for example, by:
  - Level and student background
  - Delivery mechanism
  - Intended outcomes
  - Instructor preferences

- There is thus a responsibility to *design* the GIS curriculum correctly to suit local circumstances, resources and student needs. Sample curricula can help, but a more general approach is to develop methodologies for curriculum design. An analogy we might use is between specific computer programmes (curricula) and the more general idea of programming languages (the methods and toolkits used).

2. Curriculum as a system

- There is no clear, accepted definition of the word curriculum. The dictionary definition is *a course of study*, but this gives little away and educational theorists invariably give a much wider definition that includes:
  - Explicit statements of ideology underlying the instruction (why are you teaching it, and why is the teaching the way it is?
  - General long-term aims (what are students intended to gain from following the course?
  - Specific, testable, short-term objectives (what will they be able to do as a result of following the course?)
  - Resources to be used (what is needed to deliver the course?)
  - The delivery methods to be employed (how is it to be taught?)
  - Timing of the units and their sequencing (when is it to be taught and in what order?)
  - Assessment procedures and the balance of assessments to be made (how, when and why will it be examined?)
  - A methodology for evaluating how well the course has been received (how will

the instructor acquire feedback from the students about the course?).

- A curriculum is more than a course title and list of topics or even set of lecture notes. These constitute a *syllabus* and this is only one component of a curriculum.

- A simple model of the curriculum sees it as an interacting system made up of aims and objectives, assessment and evaluation (not the same thing), teaching methods and content (Gold *et al.*, 1990):

see figure 1.

- The implications of this system view are:
  - Because changes in any one of these elements will force changes in all the others, curriculum design is a complex and difficult process, similar in many ways to the development of a software system. A commercial GIS is very similar to a curriculum. Both have a high intellectual, conceptual and technical content, but note how differently they are usually produced. More often than not in higher education the curriculum is the work of a single individual or small team following no clear design methodology, often under extreme pressure of time, and with no process documentation on the way. A large team following a formal design methodology will produce a commercial GIS and documentation will form a very important part of the process.
  - For completeness, all the elements defined above should be considered and present.
  - In theory you could start at any point in the system and begin to design the curriculum, what matters is that all the elements and their linkages are known.

- *As an exercise, think through how these approaches might be used in a practical curriculum design.*

3. Curriculum design methodologies

- GIS curricula should be designed and there are a number of formal models of the design process (see Gold *et al*., 1990; Chance and Jenkins, 1997) that are surprisingly similar to those proposed in software engineering Some questions to ask are:
  - Why is the course being taught?
  - What new knowledge, skills and attitudes do I expect my students to develop?
  - If so, what experiences do I need to provide for them?
  - Will all students benefit from the same experiences?
  - What range of experiences is possible?
  - What resources are available? What am I comfortable with, and what would I like to experiment with?
  - How will I know if the course is progressing as intended?
  - How will I know if it succeeds?

- How can a curriculum design be guided? Gold *et al.* (1991, Chapter 10) recognise six possible approaches:

3.1) Design through aims and objectives or intended learning outcomes

- This is the equivalent of a *top down* approach to software development. It starts from a clear statement of broad educational aims, refines these into a series of explicit and testable objectives, and then devises teaching strategies, content and assessment methods to meet these aims and objectives. As with software engineering, so most of the relevant educational literature tends to favour this approach.

- An educational AIM is a broad statement of the overall motivations for the course such as *to develop an understanding of the theory behind GIS and to develop skills in the application of GIS to problems in environmental management*. In contrast an educational objective is a precise statement written in such a way that it easily translates into something that can be assessed in some way such as *to understand by a practical example the basic principles of semiautomatic digitising*.

- Educationalists recognise a taxonomy of *educational objectives.* Bloom's taxonomy (Bloom, 1956) has six major categories from knowledge, through comprehension, application, analysis and synthesis to evaluation. The ordering of these categories is intended to be broadly hierarchical, each measuring a more complex behaviour than its predecessor and also subsuming it.

- The difficulty of specifying aims and objectives (for an extended discussion see Beard, 1970, pages 44-71) has led many educationalists to argue that it is better to specify a series of intended learning outcomes (ILO). Examples are provided at the head of this, and all the other, units in the Core Curriculum. The key is to specify something that the student should be able to do after following the course. For example, the aim we used above might translate into an ILO such as *'after completing this module, you should be able to use a semiautomatic digitiser to input and structure basic vector data in the ARC/INFO GIS system'*. Notice that this is very easily converted into a task that students would have to complete in the laboratory. Without such a laboratory exercise, the same ILO might be *'after completing this module, you will be able to state how line data on a map can be captured for input into the ARC/INFO GIS using a semiautomatic digitiser'*. At a higher level in the taxonomy of objectives, students might have an ILO which asks them to take an evaluative view *'after completing this module you will be able to list the advantages and disadvantages of semiautomatic digitising related to raster scanning as input for line data into the ARC/INFO GIS'*.

- The advantages of both aims and objectives and ILOs are that they:
  - Communicates teacher's intentions clearly and unequivocally
  - Provide an immediate framework for course structure and content
  - Guide the selection of appropriate teaching and learning resources
  - Help both evaluation and assessment.

- The major problem with this very formal approach in which everything is written down in advance is that once started, it is hard to change tack, possibly as a response to student feedback on the course or changing circumstances.

3.2) Design by subject matter

- An obvious way to design a curriculum is to write down a set of topics that will be taught. Many instructors (e.g. the NCGIA Core Curriculum itself) have started at syllabus and content, specifying WHAT should be taught and then gone on to consider all the other elements. This is a *content driven* approach to curriculum design and this approach is the one that has necessarily been taken by almost all the published examples in GIS. This is an approach that software engineers would recognise as bottom up. There are at least six reasons why this approach should be modified:

  Research evidence shows that *syllabus content is not what most influences student learning*. It is the precisely extra components that turn a syllabus of topics into a curriculum, such as attitudes to study, assessment tasks and so on, that most define what they ultimately remember and use in later life.

  - A published syllabus may actually hide the real content. Educationalists also talk of the importance of an 'hidden' curriculum and various departmental cultures. These form a hidden agenda of implicit demands, which may run totally counter to the explicit syllabus. In practice, assessment in the form of the examination questions set often reveals this hidden curriculum, which is why the study of past examination papers is such a useful student revision method.
  - *Content dates rapidly*. What is currently fashionable in research is often ephemera, to be replaced very rapidly by other materials. This is particularly likely to be the case in a rapidly expanding field like GIS.
  - Course content always undergoes a series of *pedagogic transformations* on the way from teacher to taught which filter and transform it. Thus the real 'content' of a course can be defined in several ways. Is it what was originally intended should be taught, what was actually delivered, what was added to this by teacher/student interaction, what the students actually wrote down, what they remembered, or what they took from the course into the world of work?

    $$C \Rightarrow C1 \Rightarrow C2 \Rightarrow C3 \Rightarrow C4 \Rightarrow etc$$

    C = what it was intended to teach.
    C1= what actually was taught
    C2= what the students actually wrote down
    C3= this content after modification by the students additional work and interaction with others
    C4= this content as it was remembered and reproduced
  - Notice:
    - Each transformation will be noisy.
    - The absence of any clear feedback loops.

  - Designs which build up in this way can be perfectly rational (the NCGIA example!) but there is a tendency for designers to lose sight of the overall course structure when using this approach.
  - These two approaches are the most common, but Gold et al (1990) recognise four other possible approaches:

3.3) Design for power

- It may well be that GIS course designers are not totally free to design as they see fit. In many countries the GIS teaching might be part of some specified national, even international scheme in which others have specified many aspects of the curriculum 'in power'. An example is where the instruction is part of a professional development or continuing professional development scheme such as those operated by some of the professions.

3.4) Design building on teacher motivations

- A seemingly radical approach to curriculum design that may be far more common than instructors like to recognise is a design, which simply builds on the motivations, experience and interest of those delivering the course. Purists will argue that this will give an unbalanced view of GIS, but there are several arguments in its favour. First, the instructor will be knowledgeable and enthusiastic and hence teach 'better'. Secondly, this enthusiasm may well be transmitted to students who respond by working harder and with greater commitment. The final result could well be a better experience than that of a course given by instructors less at ease with the material and less enthusiastic. This type of curriculum at BA/BS level often leads good students directly into Graduate School, but this is likely to be a some cost in general awareness of the field for those who do not.

3.5) Design for resource availability

- Given that there is a large number of GIS education resources such as machine tutorials, CD-ROM, WWW sites, published pencil and paper exercises, text books and vendor instruction manuals it is possible to design a curriculum that builds on these resources. In USA, it is relatively common for introductory classes to be based very closely around a standard, specified course text. There is a different tradition in UK, but the logic of this approach is beginning to be more widely accepted. It has the advantage of providing a clear 'map' of what is to be covered and in what sequence, allows students time to work on the materials out of class and thus reduces the number of steps in what above was called the pedagogic transformations.

3.6) Student centered design for individual needs and knowledge.

- Finally, and possibly the most challenging approach of all, *student-centred design* that begins by an examination of individual student needs and attempts to provide course materials to meet them. The problem with this model is that only seldom do educators 'listen to the learner' and, even if they did, it is by no means clear that students would have a correct perception of the field. The student's learning environment is a complex one that includes far more than just the formal programme of instruction. It includes interaction with other students, browsing the library, talks with parents, and so on. It should be apparent that this approach must recognise that students adopt very different learning styles, so that what is good for one may be totally inappropriate for another.

  - **The importance of feedback and critical evaluation.** These six approaches to curriculum design are theoretical models. Any one of them is unlikely to be followed in its entirety, either as a 'top down' or as a 'bottom up' system. In practice, almost everyone will chose a *middle out* strategy that designs by refinement of a central core of materials that most probably already exist. The important point is that there is a design and that all the elements of the curriculum system have been thought about.

4. Some dilemmas for GIS curriculum design: GIS and the curriculum

- In common with many new technologies, GIS has a number of characteristics that make formal curriculum design difficult:

- ***Speed of development.***
  - GIS has evolved very rapidly relative to the speed at which developments can possibly be incorporated into curriculum structure. This has had a number of consequences. Until recently, it has meant that there has been a shortage of faculty/instructors able to teach about it. Normally, in education there is a reasonable supply of qualified educators willing to enter into it. These instructors are able to draw on models of curriculum practice based on their own experiences or have a background in research and applications that leads to a pretty clear idea of what should make up a curriculum. None of these conditions is met in GIS education.

- ***Education or training?***
  - GIS is usually introduced as a technology or an industry that is technology driven, yet it rests on top of many years of work in *spatial information science* (SIS). This 'education or training' debate permeates almost all the curriculum. It clearly must influence the overall aims and objectives, but it also affects the modes of delivery and the content that is offered. The dilemma is to choose between education in the concepts of SIS and training in the use of a specific system. In part this is to do with the levels of skill needed for a variety of possible future involvements with GIS, from operative to system designer (see Toppen, 1992 for a typology of GIS careers). No single curriculum could hope to meet all these requirements.

- ***GIS or xIS?***
  - where x can be S (spatial), L (land), M (Management) or even a redefined G (geoscience). There are a number of different conceptions of the field of GIS,

depending on the background and prejudices we bring to it. For better or worse, the use of the word 'geographic' has meant that responsibility for education in GIS has mostly rested in academic Departments of Geography. This is both a strength and a weakness. It is a strength because many of the antecedents of GIS, such as computer-cartography, remote sensing and spatial analysis, were firmly located in the same place and have remained so. It is a weakness because many of the technical underpinnings of GIS (geometry, data base management) are difficult to teach in the same context. Again, no one single approach can hope to meets all these needs. From a curriculum design point of view, it is doubtful if anyone from a purely geographical background is able adequately to balance the material that goes into the curriculum or to specify educational aims and objectives that fully address what a complete education in GIS should provide.

- ***Breadth or depth?***
  - For a full education in GIS, students need the breadth of vision to understand not only the scientific and societal problems to which it might be applied, but also the complex managerial, legal and ethical questions that might arise from this use. At the same time, they must also have the depth of understanding to be able to play what Douglas once referred to as the 'hardball' version of GIS (Douglas, 1988). In the hardball version it is necessary to know about and apply concepts from data base management, computer programming, and so on, to real world problems with the inevitably 'messy' data. In his view, teaching students about the use of GIS using a 'filled' raster system is essentially playing the 'softball' variation, 'played on a smaller field, with a larger, more easily handled ball ... designed for summer camps and picnics where everyone can take part'. There is nothing wrong with softball, provided we do not pretend that it is hardball. and this is not simply a question of curriculum content. Most of the basic concepts of GIS are capable of being dealt with either as a shallow concept or in depth. For example, raster storage, regarded by Douglas as softball, can equally be approached at a depth, which is distinctly 'hardball' (see for example, Samet 1989). Balancing breadth against depth may well be the most important curriculum design problem of all.

- ***Hands on or hands off?***
  - In producing a curriculum for GIS, it is almost certain that students will need to access as powerful a system as is possible within the usual budgetary constraints. Although desirable as an end in itself, 'hands on' has some unfortunate consequences, which are discussed in the next module of this section on *Teaching and learning GIS in laboratories*.

- ***Option or integrator?***
  - A fifth dilemma concerns how we relate GIS to the rest of whatever curriculum we happen to teach. At least two models are possible:
    - GIS is a sub-set of some other discipline, to be taught as an elective within the context of a course in some other 'real' discipline. The difficulties that this view is creating for academic geography can be seen in the interchange between Taylor (1990), Openshaw (1991) and Goodchild (1991). The obvious weakness of this model is that it tends to generate teaching in

breadth rather than in depth and risks marginalising the entire enterprise.
    - GIS is a cover set integrating materials from parts of several other disciplines into one distinct science of spatial information that is worthy of study in its own right.

- ***About GIS or with GIS?***
    - Finally, although a lot of people are teaching and learning about something called GIS, far fewer seem to be teaching *with* it, that is, using GIS better to teach some other discipline (see Thompson, 1992).

5. Conclusion: What does a good curriculum look like?

- Designing a curriculum for GIS is not a simple matter and there is no single 'best' answer either in the form of the curriculum or even the methodology adopted for its design. A final question we might ask is whether or not it is possible to determine if the result is any good. One way is by always including a careful student of the course once it has been given. Evaluation of this sort is essential and should always be treated seriously, allowing sufficient time in class for any survey questionnaire to be filled out and with the results carefully summarised. It is good practice to post a notice giving the results of the evaluation and providing an instructors commentary.

- Is it possible to anticipate whether or not the curriculum meets its aims? One simple test to apply makes use of the set of *guiding principles of good education* proposed by the American Association of Higher Education (Chickering and Gamson, 1987). According to these a good curriculum should:
    - encourage staff/student contact
    - encourage co-operation between students
    - encourage active learning
    - provide prompt feedback on performance of both teacher and taught
    - emphasise `time on the task'
    - respect the diverse talents and ways of learning brought to the course by the students
    - evaluate itself
    - display a clarity of aims and objectives
    - make use of the educational literature.

- The golden rule seems to be always to remember that *WE ARE NOT JUST TEACHING GEOGRAPHICAL INFORMATION SYSTEMS BUT WE ARE ALSO TEACHING STUDENTS.*

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Curriculum design for GIS (159)

Instructors' Notes

- This unit is not typical of the other units in the curriculum in that it is primarily directed at instructors intending to use the NCGIA Core Curriculum as a resource in their own curriculum design. Alternatively, the materials might be used directly by instructors teaching the methodology of geographical education as part of an education elective within higher education. The materials draw heavily on standard educational literature, notably Brown G and M. Atkins (1988) Effective Teaching in Higher Education (London: Methuen & Co. Ltd.). Additional components related directly to teaching within a geography curriculum can be obtained from Gold, J.R. et al., (1991) Teaching Geography in Higher Education: a manual of good practice (Oxford: Basil Blackwell Ltd.).

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Unit 159 - Curriculum design for GIS

Metadata and Revision History

1. About the main contributors

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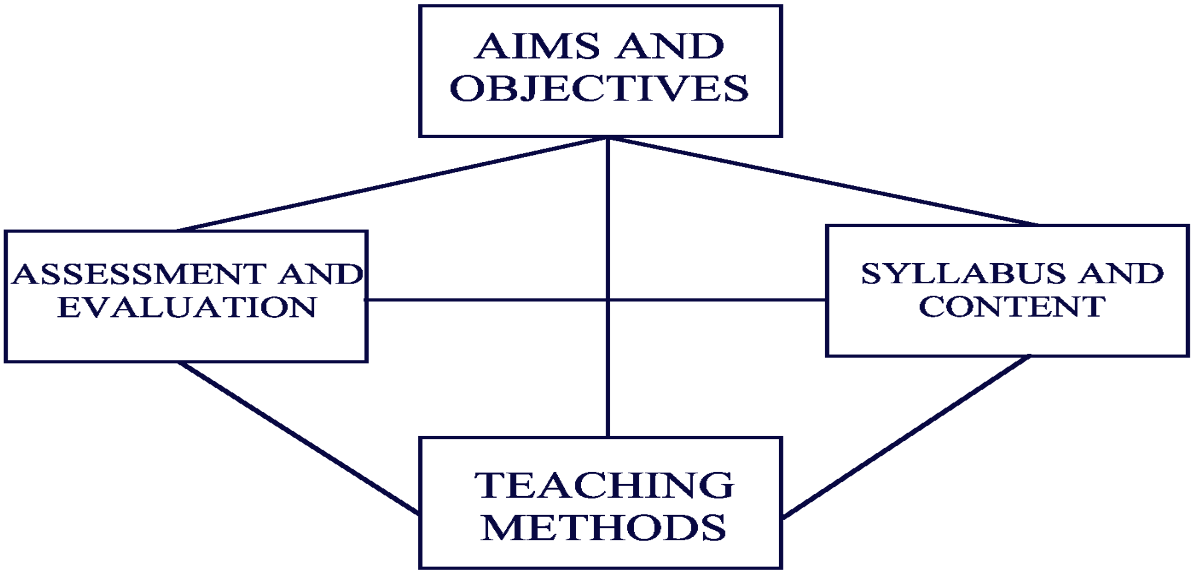
AIMS AND OBJECTIVES
ASSESSMENT AND EVALUATION
SYLLABUS AND CONTENT
TEACHING METHODS

Figure 1.

Unit 160 - Teaching and Learning GIS in Laboratories

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Advanced Organizer

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Instructor's Notes

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Metadata and Revision History

Unit 160 - Teaching and Learning GIS in Laboratories

1. Introduction - the laboratory class

- Some form of 'hands on' work is a feature of most GIS curricula. In the US, such work is often referred to as a *laboratory class* whereas in the UK, it will usually be called a *practical*. The essential idea behind a laboratory class is that, rather than being taught, *students teach themselves and each other*.

- GIS is often seen as a technical, practical subject so that aims and objectives or intended leaning outcomes will specify some form of laboratory work.

- In no other area of instruction is it as important to match what is done with the intended learning outcomes as if it is for laboratory classes.

- Laboratory classes are expensive to establish so it is important to 'make them count'.

- Nowadays we tend to think of the laboratory class as a necessary feature of most higher education, but it has not always been so. The book by David Boud and others (Boud *et al.*, 1986) makes it very clear that the laboratory class as we now know it was only introduced into Universities in UK towards the end of the nineteenth century. The objective was not to learn practical skills as such but was to help students learn scientific theory by repeating some of the classic experiments of science. It was thought that by 'looking over the shoulders of the great scientists' knowledge and comprehension would be improved, as in the Chinese proverb:

'Tell me, I forget,
Show me, I remember,
Involve me, I understand'

- During the twentieth century additional motivations for laboratory work have been added:

  - The acquisition of direct skills. In GIS these might be using a digitiser or scanner, importing data into a system, georegistering different data sets, data base searching, executing an analytical strategy and so on. At an advanced level it might also include learning to program using either a system macro-language or a standard high level programming language such as C++.
  - Gaining familiarity with equipment and software. In GIS this will involve learning the specific commands or interface to a system.
  - Using the laboratory class as a training ground for independent enquiry by students in which the theory is applied to new situations. In GIS this will involve using a system to solve a real problem.
  - Learning to record, evaluate and report results. This will introduce project management skills.
  - Often laboratory work is undertaken in groups, so that the acquisition of group work skills is an added motivation.

- There are several problems in laboratory work in GIS:
  - An inability to 'see the wood for trees'. In overcoming what can often be very difficult practical problems we lose sight of the intended learning outcomes.
  - The expenditure of a lot of effort for what at times can be seen to be marginal educational gain. This effort is counted in very long learning curves, both for teacher and taught, to become familiar with rapidly evolving and changing systems. Any direct systems knowledge acquired in class is likely to date very rapidly indeed.
  - An understandable obsession with the tools used at the expense of the understandings gained along the way. This has been called the 'Gearfreak syndrome'.
  - Much laboratory work using GIS can be very automatic (do this, then do that, ...).
  - Because the contribution of the individual student is sometimes difficult to isolate, laboratory work is difficult to assess.
  - Gold *et al*. (1970, pages 36-7) argue that the change from objectives which were to do with understanding theory to those which emphasise skills and training can be taken too far and that skills and techniques can be taught without the use of a laboratory possibly at much less cost.

2. Styles of Laboratory Work

- There is no one single model of a laboratory class. A variety of types of class can be recognised (Brown and Atkins, 1988, 99-100):
  - *Demonstrations,* designed to illustrate theory taught in lectures or to display particular skills. These can be given by the instructor, by teaching assistants, or by the students themselves. In GIS there are a number of examples of system use from vendors, and from national and other mapping agencies. A very large number of these demonstrations are now available on WWW or on CD-ROM.
  - *Controlled Exercises.* These are tightly controlled pieces of work that are wholly devised by the instructor that yield known results. In GIS, good examples are the series *Getting Started in GIS* (Langford, 1991) and the UNESCO Workbook materials developed by the IDRISI project.

- *Structured Enquiries*. These are 'lightly structured experiments which may require students to develop their own procedures and/or provide their own interpretations of the results' (Brown and Atkins, 1988, page 99). In GIS a structured enquiry might involve providing students with a data set and an objective but leaving the choice of procedure to them. This kind of laboratory class can often be produced by 'open ending' some aspect of the materials. By 'open ending' is meant giving students freedom to chose either the data set (see Unwin, 1980 for an example in statistical analysis), objectives or procedures.
- *Open enquiries.* These require students to identify a problem, formulate it clearly, develop appropriate procedures, interpret results and consider their implications. In GIS the complexity of any enquiry is likely to be such that this involves virtually the entire system development process. The approach is probably best suited to advanced work in groups.
- *Research projects.* A research project is one that is based on a long experiment, or series of experiments. Project topics might be selected by the students, instructors, or, possibly most appropriately in a GIS context, in collaboration with some local industry or authority. For example, in 1996 students following the Master's course in GIS at Nottingham University (England) worked for most of the year with representative of a local police authority to prototype a crime pattern analysis system using and evaluating different GIS system tools as they went along. The results were of use to the authority and the students gained a great deal of useful experience in project planning and management.

- As we move from demonstration to project, so there is a change in the amount of independent work that is expected of the student :

	Aim	Data	Method	Results
Demonstration	Given	Given	Given	Given
Exercise	Given	Given	Given	Open
Structured enquiry	Given	Given part or whole	Open or part given	Open
Open enquiry	Given	Open	Open	Open
Research project	Open or negotiated	Open	Open	Open

(Based on Brown and Atkins, 1988, Table 5.3, page 99)

- There is also a change in the appropriateness of these various types of laboratory class to standard educational objectives:
  - **Demonstration:** Good for knowledge and perhaps comprehension. Moderate for application and analysis. Poor for synthesis and evaluation.
  - **Exercise:** Good for knowledge and comprehension. Moderate for application, analysis and synthesis. Poor for evaluation.
  - **Structured enquiry:** Good for application, analysis. Moderate for knowledge,

comprehension and synthesis. Poor for evaluation.
- **Open enquiry: Good** for application, analysis and synthesis. Moderate for comprehension and evaluation. Poor for knowledge
- **Research project: Good** for application, analysis synthesis and evaluation. Moderate for comprehension. Poor for knowledge.

- It is clearly sensible to match the laboratory class style to the intended outcome!

3. Types of GIS laboratory class

- *Computer-free classes.* If the aims and objectives/ intended learning outcomes are solely to do with knowledge and comprehension of theory, these can often be addressed by laboratory exercises that do not involve any 'hands on' computer work at all. examples include:

    - Simple pencil and paper exercises using artificial data to illustrate concepts such as co-ordinate rotation and translation, converting a simple line map into a series of relational tables, map overlay and so on.
    - Map interpretation and appreciation of the type often seen in 'old fashioned' texts in geography and cartography.
    - Desk top GIS design studies
    - Use of videos about GIS applications
    - 'Field trips' to local GIS installations

  These have the advantage of being relatively cheap to set up and highly focussed on the particularly concepts involved. They can also generate useful materials for student assessment.

- *Learning about GIS in a computer environment.* Much of (1) can be automated and/or supplemented by computer based learning (CBL) resources of one sort or another. Several multi-media GIS instruction systems have been developed such as the GIST tutor (Raper, 1992) and the GeoCube. Similarly, the (UK) Geodata Unit at Southampton University has produced a series of computer resources to provide illustrations of many standard GIS operations. The World Wide Web now contains numerous other examples of this type of material. Developing this type of CBL material is both difficult and costly and materials brought in from outside (or on WWW) may not be entirely suited to the curriculum, but as WWW develops, so it is inevitable that this type of resource will be used more and more. It is not easy to evaluate this type of laboratory class because often no tangible product is obtained that can be assessed.

- Using a GIS to teach GIS theory. There are many resources available to enable direct use of a GIS in teaching, including several vendor-produced workbooks (see WWW sites for current details). This is probably the most common approach in GIS laboratories. It has the advantage of linking theory to practical use of a system, most probably with 'real' data. The disadvantages are those of the extra effort involved in learning a system, the cost of provision of such a system and the costs of preparation of the related teaching materials. This type of laboratory class is often 'closed' offering little opportunity for students to do anything except issue the 'right' commands. Often data capture is ignored, yet in the real world this is often the most troublesome and expensive part of a GIS project. It may be that this type of class makes GIS use look too easy!

- Learning to do GIS in a project. If the intended learning outcomes involve student exposure to 'real' GIS use and the acquisition of skills in GIS use, then the best type of laboratory class is the extended project. In this, either singly or in groups, students work though the entire GIS project cycle from problem definition, data selection and acquisition, system establishment, analysis and reporting. This type of project can be set up with varying degrees of instructor input. The problem can be specified in advance, students can be provided with a choice of data, and it is even possible to offer a choice of proprietary system. A GIS project offers opportunities for work closely related to the real world and in groups where management skills become important. Such projects are very demanding of staff time and energy and should not be undertaken lightly or without some control on student access to staff. A device that has been used successfully in several classes is for the instructor to play the role of GIS consultant whose time is rationed by a notional funding allowance.

- Note that the skills needed as a teacher to set up a successful laboratory class are very different from those involved in lecturing. In addition they involve
    - questioning, listening and responding
    - giving instructions
    - supervising the work of others
    - teaching demonstrators, and
    - helping technicians

4. Setting up the laboratory

- Setting up the physical laboratory facility to allow any type of GIS laboratory class will involve some major investment decisions.

- There is already a considerable literature on how to set up a GIS laboratory, including some useful case studies developed by the NCGIA.

- It is not easy to generalise, since local circumstances (budget, staff available) and needs (type and level of course, number of students, intended learning outcomes) vary enormously.

- In the early days GIS laboratories were very expensive to establish. Hardware and software costs have fallen dramatically, but 'liveware' has become more expensive and. increasingly, data acquisition costs can be significant.

- In an ideal world, the laboratory would exactly match the intended teaching, but this is only rarely possible:
    - Laboratories must serve several courses, including possibly courses that are not

about GIS at all.

- Most institutions will need to service several levels of GIS course. The environment needed for an introductory freshman course in GIS is unlikely to be the same as that needed for graduate school classes and research.
- Often, the provision has to be set within an external environment controlled by faculty or institutional rules relating to the purchase and maintenance of hardware and the delivery of software. The need for GIS to use very large volumes or data may well, for example, make use of a college wide server/client network difficult and lead to clashes between the institution and the GIS unit.
- Proprietary GIS systems offer different licensing arrangements and educational discounts that may strongly influence the decision as to which to use. In UK, for example, there is a single agreement that makes ARC/INFO available to all institutions in higher education at very low cost. In turn, use of this system might then influence decisions on hardware platforms needed, data formats and availability, associated instructional materials, and so on.

- A checklist of things to think about in setting up a GIS laboratory is:
    - *Space.* Is a room of sufficient size available? Remember that in addition to the computers there is a need for space for digitisers, plotters and printers, paper and maps, as well as for workspace away from the machinery.
    - *The general environment.* This is often neglected, but an important component of a successful GIS laboratory are the power supplies, tables and chairs, carpets, display boards, window blinds and so on. Most countries have a set of sometimes mandatory Health and Safety Regulations that specify how computers should be set up and run. Like any other laboratory, a GIS laboratory should be a pleasant place in which to work. Pay attention to issues of safety and security. How will students gain entry to the laboratory? When, and under what conditions?
    - *Networking.* Whatever the technology to be used it will be necessary for all the machines to have good network access and this will be in place for a much longer time period than any specific set of machines. How will the network be served and how will disk storage be rationed and controlled?
    - *Hardware.* Although this is what most people think hardest about, it can be argued that hardware purchase will be a minor part of the total costs. Compare, for example, the salary costs of the professors setting up and running the laboratory class with the cost of a PC or UNIX workstation! Nowadays, many GIS laboratories will be a mixture of PC and UNIX based machinery sharing the same network and transferring data between platforms as necessary. In costing any GIS facility it will be necessary to amortise the hardware costs. This involves making some guesses as to the effective lifetime of any equipment. Computers do not wear out in any conventional sense: they rapidly become obsolete and it is in the industry's interest to shorten this time as much as possible by new releases of operating systems and processors. For the kind of machinery needed for GIS, a 'half-life' of around three years seems appropriate!
    - *How many platforms?* How long is a piece of string? There is very little evidence on how many platforms are needed in a GIUS laboratory and this to an extent depends on the types of class that are envisaged. For a

supervised class, then it is possible to operate with two or three students working on each machine (but remember to provide space and chairs!), but for general project work then the ratio of students to machines can be somewhat higher. For what it is worth, a 1980 report on university computing in UK recommended a ratio of one workstation for every ten students but this has gradually been reduced to a strategic target of one for every four students.

- *Software.* It goes without saying that you will need at least one GIS system (see above), but do not forget any associated software that will be necessary both for teaching and research such as RDBMS, Office tools, WWW browser, image processing and so on. As with the hardware, so GIS software rapidly becomes out of date and similar comments apply. There is a (dated) review of GIS from an educational perspective by Fisher (1989).
- *Liveware.* All the evidence is that an efficient GIS laboratory, even one used solely for teaching, must be managed and supervised by full-time support staff. Although there is a temptation to do it yourself, it is NOT sensible for faculty to take on these responsibilities which will clash with other teaching and research activities. Not only do support staff have to be in place, they must also be trained and involved in the preparation of the classes they will be called on to supervise. In the longer term, some form of career path within the institution or department should be provided. It is probable that the single most difficult resource issue in setting up a GIS laboratory will be providing this support.

5. Good Luck!

- Nobody said it would be easy! *But*
- If you get them right, good laboratory classes will vastly enhance your GIS teaching.

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6.2 Web References

Educational resources to do with GIS are rapidly being made available to anyone who has access via *WWW,* and the URLs etc. are changing all the time. Good places to start a search for materials are

- The UK Computers in Teaching Initiative Centre for Geography, Geology and Meteorology site
- The NCGIA site
- The site that at Edinburgh University in UK
- For educational issues in geography there is a good site, maintained by the Geography Discipline Network

7. Review and Study Questions

1. Outline what is meant by the term 'curriculum' and list some possible approaches to curriculum design.
2. Most of the published GIS curricula are based on the specification of the content to be taught. Set down a case against this approach.
3. Why should designing a curriculum for GIS be particularly difficult?
4. Design and justify a GIS curriculum for any group of students with which you are familiar.
5. Why do GIS courses include laboratory classes?
6. Outline the problems that will emerge in setting up a GIS laboratory and the necessary resources to overcome them.

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Teaching and learning GIS in laboratories (160)

Instructors' Notes

- This unit is not typical of the other units in the curriculum in that it is primarily directed at *instructors* intending to use the NCGIA Core Curriculum as a resource in their own curriculum design. Alternatively, the materials might be used directly by instructors teaching the methodology of geographical education as part of an education elective within higher education. The materials draw heavily on standard educational literature, notably Brown G and M. Atkins (1988) Effective Teaching in Higher Education (London: Methuen & Co. Ltd.). Additional components related directly to teaching within a geography curriculum can be obtained from Gold, J.R. *et al*., (1991) Teaching Geography in Higher Education: a manual of good practice (Oxford: Basil Blackwell Ltd.).

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Metadata and Revision History

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