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Enabling progress in GIS and education

P FORER AND D UNWIN

A distinction is made between geographical information 'systems', 'science', and 'studies'. The tertiary education system has, by and large, been successful in developing GI 'systems' education and developments in GIS software have facilitated the teaching of both GI 'science' and 'studies'. The problems in implementing those perspectives are discussed in terms of a series of dilemmas related to education versus training, GIS versus XIS, breadth versus interdisciplinary depth, and whether or not GI science should be seen as an option to other courses or an integrator in its own right. In the wider world, there remains much to do to bring geographical information into schools and to provide opportunities for continuing professional development. All of this will be made much easier by the ubiquity of appropriate technology, especially via World Wide Web (WWW)-enabled GIS, and will force much more attention being given than of late to the social and economic implications of what we do.

1 INTRODUCTION

In many ways, and for better or worse, educational curricula are mirrors of society. In times of technological change they frequently reflect the impact of the opportunities afforded by evolving technology and the changing labour demands of the economy in which they sit. The advent of new, pervasive, technologies for managing and displaying digital geographical data has created a situation highly conducive to technology- or market-led curriculum developments. Notwithstanding the excellent academic rationale for the study of geographical information issues, the growth of GIS in tertiary education in the last decade cannot be divorced from more prosaic market demand factors, and certainly merits examination in those terms.

The principal aim of this chapter is not to catalogue how GIS technology has infiltrated education, or the degree to which training goals have sometimes replaced educational ones. Rather, it is our intention to reflect on the broader relationship between geographical information technology and society, and to document why GIS has an important emerging educational agenda to fulfil. This reflection starts by considering the meaning given to the acronym GIS. It will help the arguments which follow to offer three interpretations. All retain Geographical Information as the GI component, but they differ in the interpretation of the S. The mainstream interpretation is S for *Systems* (GIS: relabelled in the rest of this chapter as GISy), focusing on technology for the acquisition and management of spatial information. A second interpretation is to take the S as implying *Science* (GISc), and focus on the underlying conceptual issues of representing data and processes in space-time. The growing popularity of GISc reflects a need to move beyond the technicalities of the collection and handling of information into a deeper understanding of the meaning and limits of spatial data in an increasing number of creative analyses (Goodchild 1990, 1991d). The third interpretation is S for *Studies* (GISt), implying not simply the technical and conceptual underpinnings of the use of geographical data, but the considerable social, legal, and ethical issues which are arguably of greater importance and equal complexity. This chapter argues that, as the application of geographical information technology moves from innovation to maturity and ubiquity, our educational concerns will increasingly relate to GISt and to a lesser extent GISc, rather than to the GISy end of the spectrum.

Our thesis rests on two observations, a speculation and a logical deduction. The first observation is that digital GIS are rapidly evolving to become standard tools, influencing everyday decision-making and acquiring the potential to penetrate even such market niches as the primary school classroom and home computer system. The second observation is that this penetration of GIS is developing a dialectic with human processes which is rewriting our spatial practices, knowledge, and decision-making. This is a quiet revolution, largely hidden from the general public and little debated, but it is most evident in the use of consumer behaviour data for enhanced marketing (see Birkin et al, Chapter 51). The speculation is that, because of a number of convergent trends, we are very close to seeing a major shift in the actuality and perception of GIS. Distributed computing and new GIS architectures, plus mass marketing of data, will be key components in this. It is hard to argue that new GIS-enabled products, such as intelligent in-car guides, will not soon underlie consumer behaviour more directly and most likely influence it and our urban spatial structures quite significantly.

The logical deduction from all this is that the increased influence of GIS should be reflected in a growing educational concern, as well as a greater use by education of its capabilities. Figure 1 presents an organising framework for what we are considering. The three axes seek to illustrate the nature of GIS at four dates (1985, 1990, 1997, and 2002). One dimension represents the elite/ubiquitous use of geographical information technology. Although to date in GIS, as in Information Technology (IT) in general, Moore's law has applied and led to dropping prices and expansion of the market for potential users (Longley et al, Chapter 1), the greatest jump is now in train and relates to distributed GIS and the World Wide Web (WWW: see Coleman, Chapter 22). These have the capacity to bring GIS into millions of households and agencies. The second dimension represents the balance between a technical and an application focus. This is not simply an issue of concept versus practice. It is about the ability of users to apply spatial concepts, not necessarily wisely, with limited technical knowledge. The third dimension is the degree to which GIS is an object of study or a tool to enable study. At one end of the spectrum, we see a focus on core technical and conceptual issues, and hopefully societal ones. At the other end, the GIS is an almost invisible enabler to learning about and using spatial data. Our argument is that GIS in education is moving from a clustered position near one apex to populate much more of the space in this diagram. This shift has huge implications for: who needs education in GIS; what learning topics need to be supported; what delivery structures are most appropriate; and the balance in teaching between technical, conceptual, and societal issues.

2 TRADITIONAL GISy AT THE TERTIARY LEVEL

The problems of developing courses in GIS are well known. They have been expensive to mount, requiring scarce academic skills, technical support, and significant financial resources for hardware, software, and data. Providing them has posed substantial management challenges to institutions, departments, and individuals, and complete success in meeting these challenges has been far from universal.

Notwithstanding these challenges, or perhaps because of them, there is a case to be made that GIS educators in higher education have shown an almost exemplary concern for teaching. In his 'educational postscript' to a workshop on GIS Education and Training held in England in 1990, Britain's foremost geographer/educationalist in higher education commented upon how unusual it is for any grouping of academics, at least within geography, to show any concern for pedagogy (Jenkins 1992). Yet such concern in GIS goes back a long way (see Goodchild 1985; Poiker 1985) and is also reflected in a range of texts and symposia. Thanks to it, the novice GIS instructor can now turn to several published examples of possible syllabuses (Nyerges and Chrisman 1989; Unwin et al 1990; Kemp and Frank 1996), of which the National Center for Geographic Information and Analysis (NCGIA) Core Curriculum has been by far the most influential (Kemp and M F Goodchild 1992). Described as one of the most ambitious educational projects ever undertaken in Geography in higher education (Unwin 1991, 1992), the original Core Curriculum represented an international, cooperative effort to facilitate teaching. Unusually, it has been subjected to careful evaluation and assessment based on individual case

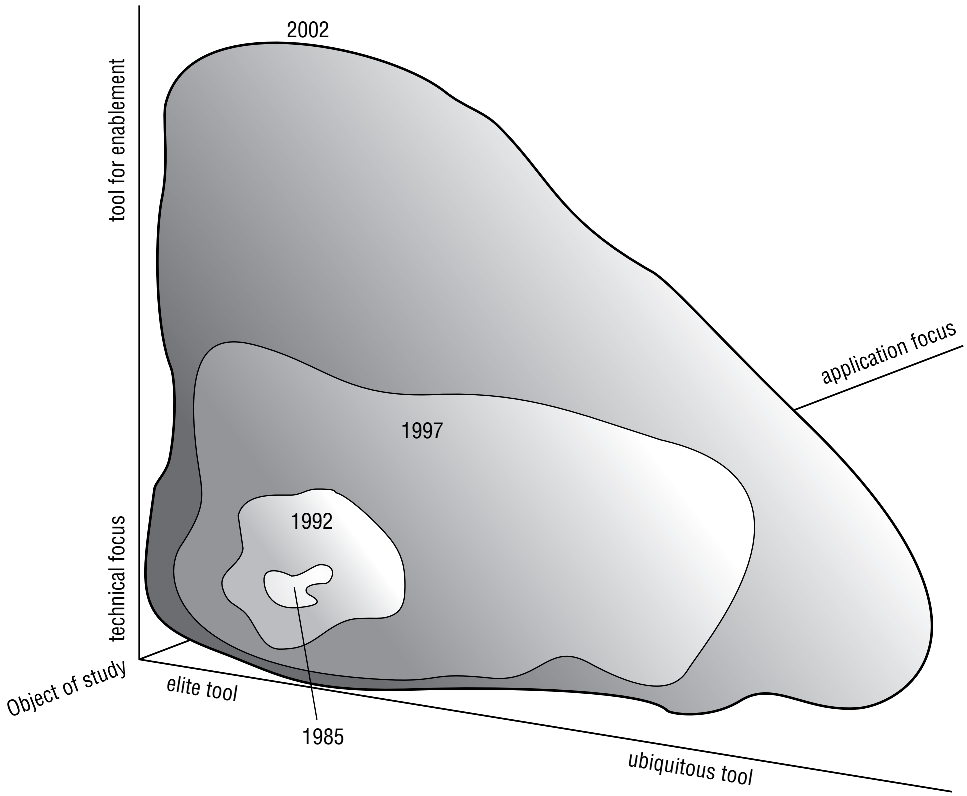

Fig 1. The changing domain of GIS.

studies (Coulson and Waters 1992) and feedback from users (Kemp 1992; Kemp and F M Goodchild 1992). Nobody, least of all its originators, would claim it to be perfect but it has given a 'kick start' to educational developments in a very large number of places. Indeed, it may well be a model for similar curriculum developments in other areas.

To be effective, a curriculum requires supporting materials in the form of textbooks, journals, software, teaching datasets, and so on. The speed of development of the GIS industry has meant that, until recently, there was limited choice of textbooks and research texts whilst journals have been hard to acquire in times of almost universal deep cuts in funding for education. However, the GIS literature has now expanded greatly. No single textbook appears to have attracted a dominant following and the options improve daily. GIS educators have produced an unusual range of other teaching resources. To help meet student needs for cheap software, a number of raster systems have been designed to run on very basic hardware (see Fisher 1989). One can add to these some very useful vendor training products (Burns and Hendersen 1989; CCGISE/IGISE 1991; ESRI 1995, 1996), some excellent computer-based tutorial systems (Raper 1992; GeoData Institute 1992; Bernard and Miellet 1996), ready-to-run laboratory materials, carefully designed packaged distance learning units (for example, Langford 1991; Eastman and McKendry 1991), a number of useful analogue videos (Hall and MacLennan 1990), and even a digital slide show (Berry 1996).

In summary, GIS education provision to date has been a success, coping with high demands for course innovation in a very dynamic area, and programmes have appeared in most tertiary education institutions. In what cannot be a complete listing, Morgan et al (1996) record over 800 academic departments that can reasonably be inferred to offer at least one course in GIS and this total clearly illustrates the operation of a broadly spread, substantial enterprise (Figure 2). Behind this progress has been an ongoing tension between student needs, disciplinary politics, and the available resources. The cost and arcane nature of GISy underlies this tension and has imposed teaching and use that requires technical skill or, just as frequently, a training in tolerating the idiosyncratic and unreliable. Characteristically, the mental model of end-use to which all this effort has been directed has been for research or institutional applications, where specific projects or defined institutional requirements set fairly rigid boundaries.

3 THE MELTING POT OF GISc

The mid 1990s saw a new use emerging, a new pattern of student demand, and new opportunities to take GIS education forward. This change was based on several factors, of which the most significant were shifts in data marketing, the advent of user-friendly GIS, distributed and WWW-based GIS, wider computer adoption, and declining overall costs. A much larger group of people now wishes to use spatial data properly, but does not understand GISc and does not have the appetite or time to master traditional GISy. For the first time, a number of low to medium cost GIS packages have emerged that can run interesting non-raster analyses on many existing office or school machines (see Elshaw Thrall and Thrall, Chapter 23). These have a basic familiarisation time to use, if not understand, measured in hours rather than months or years and some offer analytical capabilities sufficient to meet modest educational needs. This clearly opens the floodgates of GIS education far wider and enables

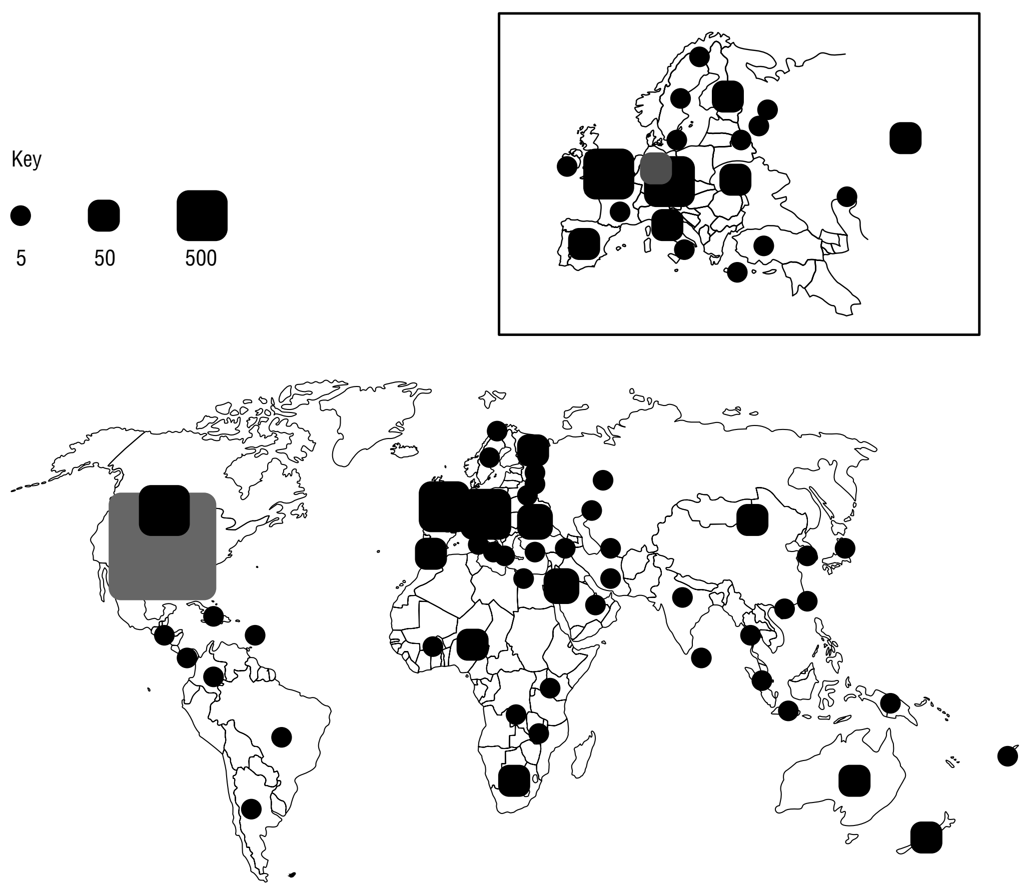

Fig 2. The pattern of global GIS education. An indicative world map of GIS education, based on the *Directory of GIS Courses*.
Source: Morgan et al 1996

broader delivery. Add to this the effects of WWW-enabled GIS, and both the users and key parameters of the educational experience are transformed. In this new environment, concepts and consequences come to the fore and the debate over the concept/hands-on learning mix is rewritten. Many researchers can be enabled with GIS without the effort needed to learn earlier systems and many users may come no closer to what was once regarded as a GIS than their WWW browser.

We can review recent progress with a similar optimism and with similar plaudits to those we gave to the early phase of GIS adoption. GIS educators have shown concern for effective learning structures and an awareness of, and ability to work with, new modes of learning delivery. The critical issue now is not how to use the new technical opportunities within established teaching aims. Rather it is how to embed them into various structures to facilitate entirely new learning outcomes. Many of these are not traditional GIS ones, and many of the academics likely to be addressing them will not be the GIS specialists. While such developments should drive the design and implementation of learning units from a conceptual stance, we know that in practice both market and technological forces are important. What, then, are the implications of this new GIS environment for GIS curricula?

4 STRATEGIC ISSUES FOR GIS EDUCATORS

All of the above unavoidably highlights some major strategic issues which need to be faced by educationists working in or with GIS. Some of these are now discussed.

4.1 Some educational dilemmas

This emerging GIS culture modifies the constraints placed on curriculum design in a number of areas and stresses new responsibilities. Five design dilemmas illustrate these changes.

- education or training?
- GIS or XIS?
- breadth or depth?
- hands on or hands off?
- option or integrator?

4.1.1 Education or training?

We have noted that the demand for GIS qualifications is driven by the need for practical skills, yet GIS rests on top of many years of work in what Goodchild (1990) called spatial information science. For curriculum design, this requires a balance between education in GISc concepts and/or training in the use of a specific system (GISy). Naturally, academics tend to favour education over training but it is by no means clear what either the industry or even the students might prefer, and employer surveys do not seem to help much in making the choice. This is one dilemma whose parameters are rapidly being changed by the emerging GIS environment. Better software and greater standardisation of concepts means that nowadays the time needed to train students to use specific systems is far less than it was, enabling a concentration on the important underlying concepts.

4.1.2 GIS or XIS?

Second, there remain several conceptions of the field. The G in GIS could be changed into S (spatial), L (land), M (management), or even a different G (geoscience: see Turner 1992). The GIS versus LIS (Land Information System) debate has already been well aired (see Dale 1992), but in some ways it has always been a pointless diversion, the strength of geography's case being its longstanding links with work in spatial processes and the various antecedents/components of GIS such as computer-cartography, remote sensing, and spatial analysis. Yet from a curriculum perspective complications arise, such as the fact that many of the technical underpinnings of GIS (geometry, database management) are difficult to teach in the same context as issues of geographical process.

The new technology also helps resolve and minimise this dilemma. It permits different kinds of users to receive different educations, breaking the technical barrier to real-world applications. We know that GIS should not be the sole preserve of any discipline since potential benefits arise from its use for virtually any discipline which addresses spatial questions. The assumption made by Taylor (1990) that such a recognition constitutes 'the imperialism of the new geography' is simply untrue. GISc takes a part of geography but adds to it concepts and methods from a wide range of other disciplines. Rather than Taylor's (1990) 'positivist geography's great revenge' or the basis for 'an empiricism that is anti-geography', the new GIS environment stresses holistic views, marginalises arguments over narrow definitions of system functions, and reduces narrow functional systems (such as LIS) to components of a larger geographical information environment.

4.1.3 Breadth or depth?

The phrase 'a bit of everything, and everything about a bit' (Toppen 1992) summarises this issue. Gold (1989) argued that this is the basic dilemma facing GIS educators. 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 (GISc), but also the complex managerial, legal, and ethical questions that might arise from them (GISt). 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).

The new environment offers at least two solutions to this dilemma. First, better access to GIS tools on the desktop allows the needs of the new users, and many of the old users, to be met with much less commitment of time to educationally peripheral issues associated with specific systems. This frees up more time for 'depth'. Second, the flexibility of the tools allows for specific kinds of user to have their needs met more precisely and more flexibly than ever before. GIS applications will thus appear in more and more contexts, again providing more scope for teaching the breadth. The down side is that the new software goes hand in hand with new access to data and new groups of GIS users who are generating more and more ethical, social, and economic issues which should be taught in tandem.

4.1.4 Hands on or hands off?

Many GIS educators seek to expose students to 'hands on' work through the medium of a GIS project, an exercise combining concept and practice in as 'real world' an environment as possible. There is much to be said for this as a basic education stratagem; it can be dignified with the name of 'student centred learning', and be argued strongly for in most teaching contexts (see Gold et al 1992). Although desirable as an end in itself, 'hands on' can have three unfortunate consequences. The 'wood may be lost sight of in the trees' of detailed project implementation, the effort is often excessive for the apparent gain and the tools themselves may become a fetish item for gear freaks. These problems provide legitimate grounds for deliberately limiting hands-on time in favour of developing concepts. Commonly too, the simple unavailability of the right tools for the right kind of hands-on learning has hindered more ambitious plans. The new environment certainly reduces this dilemma, because of both lower costs and better usability, and because of the capability to distribute GIS experiences of various sorts over internal and external networks.

4.1.5 Option or integrator?

Finally, GIS educators have agonised over where GIS should be located within the education system. Is it just a subset of some standard discipline, to be taught as an elective within that discipline, is it a branch of geographical science, or is it a discipline (GISc again) in its own right? The difficulties that this debate has created within academic geography can be seen in the interchange between Taylor (1990), Openshaw (1991), and Goodchild (1991b) and the set of essays in Pickles (1995; see also Pickles, Chapter 4). The new environment seems unlikely to resolve this issue in any coherent way. GIS has penetrated very widely into education and this will strengthen its position as an option within numerous user disciplines. However, at the same time, the growing capabilities of GIS and the growing implications of their use will ensure an ever increasing mass of material critical to, and legitimately reformulated within, the scope of both GISc and GISt.

4.2 GIS in the wider educational world

Most of the preceding discussion has looked at educational issues in GIS *sensu strictum* at the tertiary level. Proposals for learning about GIS at high school level or below underscore the impact of easy-to-apply mapping and spatial analysis. Initiatives of various degrees of formality have been taken below the tertiary level in a number of countries (Bednarz and Ludwig 1997). These attract both 'gee whiz' support and some scepticism about the value of applying technique where concept should be more to the fore. Deconstructing these opposing views is often to refight the debates between empiricists and social theorists but it should be noted that the use of a GISc approach exposes schoolchildren to a range of concepts important in everyday wayfinding, such as grid systems and map coordinates. It can teach and enhance map-reading skills and it can also extend and synthesise other information technology skills. With the publication of key public data, such as census statistics and local authority development plans in GIS usable form, the civic skills argument for an appreciation of basic GISt also gathers strength. To some degree, much of this learning may be informally or incidentally provided through GIS-enabled learning resources, as described below. It may also become a curriculum feature as more countries look to institute new curricula in which information technology is emphasised.

GIS can, of course, be used as a tool for learning delivery of systematic topics. Arguments for applying GIS in this way have been advanced elsewhere (Unwin 1991), most cogently by Thompson (1992). Surprisingly little work published within the GIS literature has described this type of use. The list of published work includes an account by Maguire (1989) of his use of the BBC Domesday system, Dodson's unit on the von Thünen land use model (Dodson 1991), and a proposal to create a basic GIS resource, Nga Ohaki Aotearoa, as a learning resource about New Zealand (Forer 1989). Undoubtedly the most ambitious development to date has been 'The Geographer's Craft', a project at the University of Texas, which combines elements of GIS and Web-based resource delivery in exciting and innovative ways (Foote 1994).

This dearth of accessible published work and evaluation reflects several issues. For instance, those with GIS skills have been more than busy enough managing the growth of GIS without entering into the additional difficulties generated by the world of computer assisted learning. Until recently, the delivery of material to large numbers of schoolchildren required far too many resources; moreover, computer assisted software engineering (CASE) tools and data to facilitate the preparation of computer based learning units were unavailable or almost as difficult as GIS to master. With the breakdown of many of these restrictions, notably through the arrival of almost ubiquitous tools related to the WWW, new material can emerge, often on a local basis, but with an eye to wider distribution. The University of Auckland Geography Department, for example, now delivers initial GIS experiences within systematic courses in Physical and Human Geography, using topical examples such as local volcanic eruptions. We are aware of numerous other examples which are easily located by anyone with access to the WWW but which are unlikely ever to be described in either the GIS or the education literature. For a recent example of the integration of a traditional textbook with a compact disk containing WWW-compatible authoring, GIS functionality, and environmental modelling tools, the reader is referred to McGuffie and Hendersen-Sellers (1997).

4.3 Professional development in the geographical information industry: a neglected field?

In almost all the literature on GIS education it is assumed that what we teach will be studied as a precursor to a career within the geographical information (GI) industry. Having learnt it in class and in the educational laboratory, students go out into the real world to do it. Yet, if we examine those who are currently working in the GI industry, only a fraction of them have actually entered it by way of this academic path and there are at least three further routes into GIS which educators often forget. First, many working in the GI industry are at some midway stage in a career in information technology and may, or may not, have qualifications in academic geography or GISc. Second, many enter by way of a career progression directly from school without any formal qualifications. Third, a substantial number enter through qualifications in a relevant profession which is now using GIS, such as land survey, management, marketing, or town planning. Most of these GI professionals are thus self-taught or have simply attended one or other of the vendor courses in GIS. They may have some informal qualification, but there is no single national or international body that regulates these in the way in which, for example, professionals become accredited for practice in law, town and country planning, information technology, and marketing. In the UK, the Royal Institution of Chartered Surveyors (RICS) validates several of the taught Masters courses in GIS and successful completion of such a course can lead to exemptions on the way to a professional qualification, but not all working in the industry would approach GIS from this survey-driven viewpoint.

These types of GI professional have education and training needs which are not being well catered for and which are very different from those of the standard academic graduate. What is needed is what are often called professional development (PD) and continuing professional development (CPD) schemes. The future development and maturity of the GI industry will necessitate the formal schemes for professional development, individual accreditation, and course validation which are a feature of any developed profession (Dale 1994). In the UK, for example, members of the Association for Geographic Information (AGI) have expressed a clear wish that it become proactive in this field (Rix and Markham 1994). Similar views have been expressed in the USA, and for the perspective of the survey and mapping profession see British Cartographic Society with Survey and Mapping Alliance (BCS/SMA 1992). This desire for formal qualifications to practise in the GI industry is not universal: for a dissenting view see Barr (1995). It is also clear that the professional educational and training needs will differ from what is currently offered and from profession to profession, but as yet we do not have a clear idea of them, with confused signals from both the industry and the training providers. A particular tension lies in the objectives that any such provision addresses. At the extreme, and as seen elsewhere in this chapter, this is between direct industrial training in system specifics and more general education in geographical information science: as yet, we have very few studies which attempt to resolve this.

Three complementary approaches might be used to establish professional development needs. The first and possibly the simplest is to ask GIS vendors, users, and trainers what they see as being required. This is the approach taken by the AGI, as reported by Unwin and Capper (1995). From 1993 onwards, and taking advantage of the 'umbrella' nature of its membership which includes vendors, users, data providers, and educators in the same association, AGI has held a series of workshops that have attempted to define and structure the education and training needs of the industry. The scheme is based on one devised by the British Computer Society (1991) in what it calls its Industry Structure Model. In effect, this consists of a large matrix in which rows are levels within the industry and the columns relate to specific competencies or streams. In their careers individuals can progress, with supervision, through this matrix by moving along a row (changing streams) or by moving upwards to another level (getting promoted). The AGI variant of this model recognises six levels from Skilled Entrant to Principal/Managing Director and six streams (Design and Build, Data Acquisition, Data Management, Data Visualisation, and Human Issues) and provides full job descriptions and statements of training needs for each of the 36 possible cells in this matrix.

An obvious difficulty in the AGI approach lies in its reliance on the representativeness of the views of the authors of the scheme. The resulting model may well bear very little relationship to the reality of the GI industry. An alternative and complementary second approach is to survey the actual roles played by individuals in the industry, the skills they possess, and the skills they report as being necessary in fulfilment of their roles. Training needs can thus be seen as the mismatch between skills possessed and those seen to be necessary. This is the approach that has been adopted by the Australia and New Zealand Land Information Council (ANZLIC) reported by Sharma et al (1996) and ANZLIC (1996). Their work is based on 834 questionnaire returns in which respondents identified themselves as belonging to one or other of five basic occupational groups and levels. Analysis of these led to the establishment of a set of GIS skills profiles. It is interesting to note that there is at least some communality between these empirical results and those identified by AGI. Interestingly, their study concluded that much of the training needed was already in operation; what was seen to be needed is more focused packaging of these opportunities, greater coordination and flexibility, and some form of national competency standard.

Surveys of the type reported above can only describe the industry as it is, not how it might wish to see itself. A third approach to defining education and training needs that has a superficial attraction is to use the evidence of job advertisements. What seems to emerge from this is that, just as educators and trainers need to understand the industrial requirement, so prospective employers must have an understanding of what is possible and realistic. Sharma et al (1996: 3) note that there is a tendency for 'walk on water'-type advertisements. A probably hypothetical but entirely believable example of these is '. . . essential, expert knowledge of three leading GIS packages, two relational database packages plus UNIX guru status; desirable, postgraduate degree in statistics, electrical engineering, and business accounting' (Skelly 1996, cited by Sharma et al 1996).

5 FUTURES IN GIS EDUCATION AND THE ROLE OF GISt

The main theme to emerge from this review is that technology will to a significant degree cease to block progress in learning GIS. For a few specialist graduate students in Computer Science and Geography intending to enter the academy or industry as GISc and GISy specialists, GIS will remain an arcane and possibly difficult branch of their disciplines. But for the vast majority of people, it will be simple to use and accessible. Practice will come with the use of various WWW-enabled spatial decision support tools and from greater integration of digital spatial data tools within other learning resources. Educators should not need encouragement to seize these opportunities and focus on the growing conceptual issues needed by such everyday uses. More time can be given to issues such as data quality, error propagation, or fuzzy objects. For many users these will become more relevant as their data use increases.

During the next decade, the boundaries of GIS will have been pushed much further back and the architecture of GIS is likely to be radically altered. New analytical techniques, such as intelligence agents, may combine with enhanced WWW environments to produce new dimensions in performance and applications. Beyond this, however, will still be a species applying some key spatial concepts to address its spatial problems. There will remain a range of social and economic issues typical of any technological advance but which in GIS is both under-researched and under-represented in both media and curricula. During the last decade GIS educators have focused on technology and technique in order to enable a revolution. Attitudes to spatial data have also been transformed by the promise of profit, which has raised issues of intellectual property and privacy (see Curry, Chapter 55; Rhind, Chapter 56). The next ten years will see society employ GIS tools ever more widely and these issues will be worked through in practice. Their resolution may be an important factor determining the kind of society which results.

The future of education in GIS is replete with new opportunities, riding on the back of yet further technical progress. This progress creates both a demand for more education and opportunities for new practice. It also ensures wider and wider use of GIS as a tool for spatial thinking and decision-making. The research and teaching agenda is moving, inexorably, beyond the technical and beyond the realms of spatial science (at least if the word science is to retain its true meaning). It is also confronting – or should be confronting – a range of important social and policy issues in a critical manner. It is in these areas, as much as in the core area of spatial thinking, that the real educational challenge of GIS lies.

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