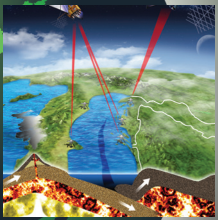
Teaching Geographic Information Science and Technology in Higher Education



Editors

David J. Unwin | Kenneth E. Foote | Nicholas J. Tate | David DiBiase

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A John Wiley & Sons, Ltd., Publication

This edition first published 2012

Wiley-Blackwell is an imprint of John Wiley & Sons, formed by the merger of Wiley's global Scientific, Technical and Medical business with Blackwell Publishing.

Registered office: John Wiley & Sons, Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK
Editorial offices: 600 Garsington Road, Oxford, OX4 2DQ, UK
The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK
111 River Street, Hoboken, NJ 07030-5774, USA

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Library of Congress Cataloging-in-Publication Data

Teaching geographic information science and technology in higher education / David Unwin . . . [et al.].
p. cm.
Includes bibliographical references and index.
ISBN 978-0-470-74856-5 (cloth)
1. Geographic information systems–Study and teaching (Higher) I. Unwin, D. (David John)
G70.212.T36 2011
910.71′1–dc23

2011022718

A catalogue record for this book is available from the British Library.

This book is published in the following electronic formats: ePDF 9781119950585;
Wiley Online Library 9781119950592; ePub 9781119962434; Mobi 9781119962441

Set in 10/12.5pt Minion by Aptara Inc., New Delhi, India.

First Impression 2012

Contents

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David, formerly professor of geography at Birkbeck College in the University of London is now retired. He was one of the team that established the *Journal of Geography in Higher Education* and in 2006 received recognition from the US *University Consortium for Geographic Information Science* as *Educator of the Year*. In 1999 his work in establishing its continuing professional development scheme led to the award of the UK *Association for Geographic Information's Past President's Prize*. He has experience of teaching GIS&T in universities in the UK, Canada, New Zealand and the USA. With David O'Sullivan he is co-author of *Geographic Information Analysis*, also published by Wiley.

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Ken is a professor of geography and former department chair at the University of Colorado at Boulder. His interests focus on improving geography in higher education, learning technologies, and GIScience, particularly multimedia cartography. He has served as president of both the *Association of American Geographers* (AAG) (2010–11) and *National Council for Geographic Education* (NCGE) (2006). He edited the *NCGE Pathways* series for geography educators (2000–05) and was the North American editor of the *Journal of Geography in Higher Education* (1999–2003). He received the AAG's Honors in Geographic Education in 2005.

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Nick is senior lecturer at the Department of Geography, University of Leicester. He was PI and Director of the Spatial Literacy in Teaching (SPLINT) CETL from 2005–10, where he directed the pedagogic activities across the consortium (University of Leicester, University of Nottingham and UCL) towards the development of geospatial technologies and spatial thinking for a predominantly graduate audience. He is currently GIS section editor for *Geography Compass* and has been on the editorial board of three other journals. He has also served on a variety of committees for the AGI, RGS-IBG and RSPSoc. With Peter Atkinson he is editor of *Advances in Remote Sensing and GIS* and *Modelling Scale in Geographical Information Science*, both published by Wiley.

David DiBiase

David led the *Penn State Online* certificate and Master of GIS degree programs in GIS from their inception in 1998 until 2011. The certificate program earned ESRI's *Special Achievement in GIS* award in 2004, and the masters program earned the *Sloan Consortium's* 2009 award for *Most Outstanding Online Teaching and Learning Program*. David led the editorial teams that completed both the UCGIS *GIS&T Body of Knowledge* and the US Department of Labor's *Geospatial Technology Competency Model*. He participated in the URISA Certification Committee that helped established the GIS Certification Institute, and served as GISCI President from 2010–11. In August 2011, David moves to Esri as Director of Education, Industry Solutions.

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Foreword

Information about the Earth's surface, about the nature of places and the routes that connect them, is vital to almost all aspects of life today. For centuries such information has been captured and disseminated in the form of maps, but in recent decades a suite of new tools and technologies has become available that has vastly increased the range of what can be captured and how it is applied. Today we make constant use of the Global Positioning System, online mapping services such as Google Earth, imagery captured by Earth-orbiting satellites, and the analytic capabilities of geographic information systems. Moreover the need to solve problems that arise in developing and using these geographic information technologies, and the need to discover general principles that can be used to improve them, are of sufficient significance and difficulty as to constitute a research field of their own, a field known as geographic information science (GIScience).

One of the most pressing of the problems of geographic information science and technology (GIS&T) concerns representation: how to design an effective and efficient way of capturing the infinite complexity of the geographic world in the absurdly limited space and two-character alphabet of a digital computer. We have learned over the past four decades that such designs involve a host of choices: what to capture and what to leave out, which of innumerable coding schemes to use to convert geographic reality into a binary sequence, and how to make the result understandable by any application system. GIS&T is not a simple matter of a few rules, but a complex world of nuanced alternatives that requires an understanding not only of the technology, but also of the geographic world that the technology is attempting to represent. The fundamental principles of GIScience include some that reflect the nature of computational systems, and some that concern the ways in which the geographic world itself is organized.

Just as there are numerous choices in GIS&T, so also are there numerous choices in how GIS&T is taught. How should we balance training in the technical details of today's technology, with education in the principles, that will still be true when today's technology is a memory? Who are we teaching: the researchers of tomorrow or the next generation of practitioners? How should we balance open-source and commercial software products, and how should students be exposed to them? What is the appropriate mix of lecture, practical exercises, and individual or group projects?

When I started a course in GIS&T over thirty-five years ago I had little doubt of who my audience was: university students majoring in geography who would go on to careers in the fields traditionally staffed by professional geographers, as teachers, environmental consultants, or location analysts. Even then, knowledge of the rapidly expanding field of GIS&T would give them a valuable edge in competing for such jobs. Courses like this proliferated, and GIS&T slowly evolved into a recognized professional qualification. Yet today the situation we face could not be more different. In addition to an ever-increasing demand for professionals, universal access to at least a minimal set of geographic information services has raised a different set of questions: in addition to asking what the professional needs to know, we also need to be asking what *every* well-educated citizen needs to know. While online mapping tools may appear to make working with digital geographic information easy and straightforward, in reality it is all too easy to make mistakes and false inferences, to endanger personal privacy, and to engage with many other ethical issues. We teach mathematics and language skills to everyone – should we not also be teaching some subset of GIS&T to everyone?

This question is becoming more and more important as the phenomenon of *neogeography* takes hold and makes everyone both a consumer and a producer of geographic information. The costs of entry into map-making have declined effectively to zero, and services such as Google's MapMaker now allow anyone not only to make their own maps, but also to contribute geographic information to central repositories where it can be accessed by anyone. Unlike the maps of the past, these new maps are personal, up to date, cheap to produce, and readily distributed. Moreover the people making them, needing a basic understanding of parts of GIS&T, are in many cases long past their period of formal education.

This book provides a very welcome review of the issues surrounding the teaching of GIS&T in higher education. Some of them are longstanding, while others have arisen only recently, and all are being impacted by the rapid evolution of the technologies, the abundance of new research results, and the changing social role of GIS&T. The community of practice that has assembled the book includes many of the world's leading thinkers about GIS&T pedagogy, and its leading innovators. Together its chapters present an intriguing range of options and choices, and much food for thought.

Higher education finds itself today in a state of transition. The traditional notion of public higher education is under threat in numerous parts of the world because of budget pressures; today's students have grown up with advanced technologies and have adopted very different approaches to learning; online and student-centered learning are on the rise; and undergraduates are expected to acquire substantial levels of personal debt. GIS&T, with its strong employment prospects, high-tech appeal, and engagement with many of the major issues facing society, may be better able than many fields to withstand contemporary pressures and better able to adapt to the evolving academic environment.

I have always derived a great deal of satisfaction from the privilege of being able to teach GIS&T to generations of students. If this book achieves nothing else, I hope it helps others to think creatively about their own teaching, and adds an increment to their own satisfaction.

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Editors' preface

This book is the outcome of a series of meetings beginning with sessions at the Association of American Geographers annual meeting in San Francisco in 2007 originally organized by David DiBiase, and conversations amongst the editors over a number of years. In the face of an increasing body of work on the subject of GIS&T pedagogy we felt a volume that attempted to assess where we have come from, where we are now, and where to go in the future, was overdue. Specific impetus came from education initiatives such as the SPLINT CETL in the UK, publication of the *GIS&T Body of Knowledge* and the *Geospatial Technology Competency Model*, and numerous workshops and papers sessions at the meetings of University Consortium for GIScience, Association of American Geographers, and National Council for Geographic Education in the US, and the European GIS in Education Seminar and GIS Research UK meetings in Europe in which we were involved, and which evidence the wealth of activity in this area. This book is timely given the recent strides that GIS&T has made onto the web, onto the mobile/cell phone and via *neogeography* into the broader consciousness. Higher education has also been subject to considerable change and in part as a response to the demands of learners the place of formal face-to-face traditional education is now contested as never before.

The contributors to this book are drawn primarily from the USA and UK with additional contributions from elsewhere in Europe and Australia, and the twenty nine chapters are organized into five sections and a conclusion. We have taken the slightly unusual step of including a commentary in which we variously provide a synthesis and forward look for each main section.

As always, the process of getting an edited volume together relies on a great number of people in addition to the editors and contributors. In particular we would like to acknowledge the efforts of all colleagues who provided review comments for the contributed chapters (several for more than one). These include:

Sarah Battersby
Robert Bednarz
Allan Brimicombe
George Chaplin
Peter Dana
Mike DeMers
Michael deSmith
Eric Fournier
Mark Gahegan
Mark Gillings
Michael Goodchild
Richard Harris
David Howard
Andrew Hudson-Smith
Alan Jenkins
Ann Johnson
Joseph Kerski
Khusro Kidwai
Andrew Lovett
Robert Maher
Duane Marble
Ulrik Mårtensson
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Lynn Songer
Josef Strobl
Su-Yin Tan
Ming-Hsiang Tsou
Wei Tu
Nigel Waters
John Wilson

In addition we would like to thank Alex Szumski (Leicester) for administrative help as well as the Wiley editorial team (Fiona Woods, Izzy Canning and Rachael Ballard in particular). The usual thanks for forbearance go to Polly, Isobel, Sophie and Cindy.

David J. Unwin, Kenneth E. Foote, Nicholas J. Tate, David DiBiase
London, Boulder, Leicester and University Park, 1 April 2011

Section I

GIS&T in the academic curriculum – introduction

1

GIS&T in higher education: challenges for educators, opportunities for education

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1.1 Overview and historical context

This book is an effort to document three decades of innovation in geographic information science and technology (GIS&T) education, to take stock of lessons learned, to identify new developments and to flag directions for future advances. These issues will be of interest to those directly involved in GIS&T education as well as a wider audience. This is because GIS&T education has benefited from various innovative developments and many of the issues, techniques and lessons learned are perhaps of wider value to other disciplines and to professions that are beginning to use GIS&T. Innovations in e-learning, open source software, and open educational resources all received a substantial push from GIS&T educators. A more important hallmark of the field is the way GIS&T educators have worked cooperatively across disciplinary and national boundaries to innovate and improve practice. We see such collaboration – what we might now term a type of *community of practice* – as a defining quality of GIS&T and as a model that might be emulated more widely in geography and elsewhere. Our hope is that by documenting features of this community, this will not only be of interest for its own sake, but will encourage others to follow similar pathways.

To understand how we reached this point, it is useful to set the development of GIS&T in brief historical perspective. Geographical information systems (GIS) are computer systems developed for the collection, storage and processing of information referenced to some form of location coordinates, with this location information usually being a key element of any analysis. Histories, such as that edited by Foresman (1998), usually cite the *Canada Geographic Information System* (CGIS) of the mid-1960s as the first such system. Essentially

Teaching Geographic Information Science and Technology in Higher Education, First Edition.
Edited by David J. Unwin, Kenneth E. Foote, Nicholas J. Tate and David DiBiase.

CGIS was an attempt to create in a computer a digital geography of the country using as its input scanned copies of conventional maps. In spirit this was not unlike the pre-computer *Land Systems* inventories conducted in Australia but the entire enterprise was constrained by the available technology. At the same time a number of people began to experiment with methods for creating maps using the computer, with a major development being initiated by Howard Fisher at Harvard University in the creation of the SYMAP mapping program. In retrospect, SYMAP was primitive, making use of a standard line printer for its output and coding its 'geography' by means of a simple raster of location coordinates, but it opened many people's eyes to the potential and rapidly led to systems making use of simple pen plotters and, eventually, light pen and cathode ray tube technology that allowed user interaction with the mapping process. A third input into this development during the same period was that of dedicated image processing hardware and software systems to facilitate the analysis of remotely sensed imagery from a rapidly increasing number of earth orbiting satellites. It was easy to see the potential of combining these technologies, even if their integration was some years ahead.

In fact, the term 'GIS' was not much used until the mid-1970s, by which time it had started to appear more frequently particularly in the context of academic meetings. By the late 1980s and early 1990s GIS had clearly gained a foothold in various academic programs at both undergraduate and postgraduate level and this in turn led to the explicit development of what Goodchild (1992) termed 'geographic information science' (GISc or GIScience). As noted by Tate and Unwin (2009) the history of GIS (or GISc) education can be related to the complex and dynamic interaction between technology, the GIS industry and the academy. Table 1.1 is a summary of Tate and Unwin's (2009) brief discussion of technology and trends in GIS education over the period of the last 30 years.

Goodchild (1998) similarly reflected on the historical development of digital computing/ GIS (albeit not with an education focus) and noted that GIS technology was then (1998) at the 'middle of the growth curve' somewhere between 'the computer as an information system' (stage 2) and fully 'digital worlds' (stage 3) with a more pervasive role in 'new societies' (stage 4) envisaged, but not yet realized. Arguably the 'typical technology' identified

Table 1.1 Technology and trends in GIS education

Date	Typical technology	GIS education typified by
1980s	Main frame/workstation	Niche programs (often at taught postgraduate level) in small number of geography departments; teaching *about* GIS&T with emphases on teaching in depth and training to use the available systems
1990s	Desktop/PC	Broadening and deepening to other geography departments/ disciplines together with the emergence of teaching *with* GIS&T, and the notion of a 'GIScience'. Learning outcomes associated with breadth of vision introduced and the collaborative development and diffusion of teaching resources such as the NCGIA 'Core Curriculum'
2000+	Mobile device/web 2.0/ virtual globe	GIS&T became mainstream, with the 'location' variable used ubiquitously and the consequent emergence of 'neogeography' and a loosening of links to academic geography. GIS is 'everywhere and no-where'

as characteristic of the date period 2000+ in Table 1.1 (such as Web 2.0, virtual globes and the ubiquity of the location variable in various mobile devices) that have enabled user-driven neogeography/VGI are hallmarks of this much more pervasive role. There would seem to be growing evidence that we have indeed reached stage 4 that Goodchild subsequently described as the full 'democratization of GIS' (Butler, 2006). Notwithstanding the complex relationship between GIS technology and people (Harvey and Chrisman, 1998) there appears to be little doubt that technological developments have, on the one hand, allowed more people to access GIS and to 'do GIS' as well as on the other hand enabled new learning opportunities and modes of learning such as e-learning and active learning to facilitate teaching (or learning) both *with* and *about* GIS. In relation to the former we have adopted the term 'geographic information science and technology' (GIS&T) in this book in deliberate reference to the specific technologies which both constitute and are specially shaping GIS and GISc. At the time of writing these encompass the web; internet; mobile and cellular technologies; GNSS such as the US Global Positioning System (GPS) and European GALILEO; satellite-borne sensing, ranging and communication systems; and pervasive and cloud computing technologies. This constellation of technologies still involves the collection, storage and processing of geospatial data, but in very different software and hardware configurations than were used even a few years ago. Critically, the 'democratization of GIS' with GIS being 'everywhere and no-where' has profound educational implications not only for who is doing the learning and what needs to be learned (Goodchild, 2011) but also for who is doing the educating and how. Not only could GIS&T education proceed without much involvement of academic geography, but this could take place without much formal involvement of the academy at all.

1.2 Why GIS&T has challenged educators

The rapid pace of the technological transformation of GIS&T as depicted in Table 1.1 has been matched by rapid innovation in education (Foote *et al.*, 2010) often in response to distinct challenges. From Table 1.1 we can see that in less than two decades GIS&T education has moved from a few niche courses in a small number of academic departments to being a major element of almost all geography and environmental studies programs and a growing presence in other disciplines as well. This expansion responds in part to the dramatic growth in demand for high-quality education and training as the GIS&T industry has spread into new commercial markets, and into more government agencies and NGOs (Gaudet *et al.*, 2003; Phoenix, 2000). Equally important in spurring innovation has been the diffusion into disciplines across the social, natural and engineering sciences. These efforts have presented formidable challenges to educators with some (such as how to fund and maintain needed hardware and software) more concrete and practical, but others more theoretical and conceptual (such as how best to reorganize and rethink traditional and sometimes hidebound disciplinary curricula and adopt new teaching methods in the context of this rapidly evolving field). Among the many challenges faced in teaching GIS&T are:

1. Its very recent evolution as a distinct branch of science, which meant that there was little past 'received wisdom' on which educators could rely and, for those faculty just beginning to teach, little guidance learning and teaching materials and curriculum

plans. Comprehensive textbooks did not appear until the late 1980s and, even then, the very first (Burrough, 1986) actually focused on land resources assessment, rather than GIS&T alone. This is a general issue: the absence of such resources is a problem that will be encountered in many fields new to the academy.

2. Its cross-disciplinary nature, which generated issues of pedagogic transfer across disciplinary boundaries. This also raised the issue of 'ownership' of the entire GIS&T enterprise. In the UK for example, the Royal Institute of Chartered Surveyors (RICS) initially tried to capture the GIS&T field by funding the development of an early curriculum (Unwin *et al.*, 1990). In USA there were similar moves from lobbyists and trade groups representing the surveying and photogrammetry professions to bring the GIS enterprise under its wings by suggesting that practitioners would have to be qualified as professional land surveyors before being allowed to drive their GIS.
3. Its heavy emphasis on technology, which generated issues of delivery, especially of hands-on practical work involving considerable investment in hardware and software. Times have changed, and the costs of computation have dropped dramatically, but similar problems are likely to occur in almost any field that is reliant on some relatively expensive technology to which students need exposure.
4. An initial lack of qualified people to instruct, which generated a problem in course provision. The dangers here are those of hiring staff only marginally well-qualified to teach and lacking in the experience necessary to build appropriate courses.
5. Its international character, which led to numerous attempts to internationalize teaching through distance learning (for example Birkbeck London's GIScOnLine, the UNIGIS consortium and Esri's Virtual Campus). These pioneering efforts reveal important issues about the comparability of nomenclature, standards and expectations used in different nations and higher education systems (Harris, 2003; Elsner, 2005; Phoenix 2004). As other disciplines travelling the same way will discover, it is one thing to develop internet teaching resources but quite another to develop appropriate course management, teaching styles, quality assurance and business models that make the offering sustainable.
6. Its role as an integrating or enabling technology with the broad domains of navigation, surveying, positioning, remote sensing and mobile infrastructure have meant that it is becoming a ubiquitous technology, but one not always well understood by users. It can be seen by many as something that is somehow 'obvious' but where failure to understand fundamentals could lead to uncritical use of what greater understanding would have shown to be very sharp tools (Openshaw, 1993). An obvious example of this lies in the very many maps now seen that have been easily drafted using modern tools but which disobey even quite basic cartographic principles (Unwin, 2005).
7. There was, and to an extent this remains today, a very strong 'professional' interest necessitating the development of professional education in systems not initially designed to provide it. Again, this is an example of what is rapidly becoming a more general issue for educators as the public rightly demands a greater and greater level of accountable professionalism in almost all walks of life.
8. The central challenge is that GIS&T is changing so rapidly. Preparing effective courses and curricula is like aiming at a moving target and requiring, among teachers especially, a special commitment to stay abreast of constantly changing concepts, techniques and tools.

GIS&T educators have responded effectively to these challenges and have, over the past three decades, led a substantial number of improvements in Higher Education (HE). Problem-based learning, active pedagogy, open educational resources, web-based instructional materials, e-learning, professional training and certification, and other innovations have all received a push from GIS&T educators (Carver *et al.,* 2004; Clark *et al.*, 2007; DiBiase, 1996). Repeatedly, GIS&T educators have been among the first to take advantage of new developments (Benhart, 2000; Deadman *et al.,* 2000; Giordano *et al.*, 2007; Keller *et al.,* 1996; Wentz and Trapido-Laurie, 2001; Zerger *et al.*, 2002). More recently a new challenge has been how to make best use of web-based mapping including virtual globes, mash-ups and VGI, which have allowed these GIS&T to be used more widely in non-specialist learning and teaching settings, and helping to spur the neogeography movement under the banner the important truism that 'geography is everywhere'.

1.3 Creative responses: a record of innovation in GIS&T education

Perhaps as a consequence of the magnitude of the various educational challenges posed by GIS&T, what is unusual in HE Geography (see Jenkins, 1992), is that its practitioners took pedagogy seriously and widespread (often international) collaboration became the norm. The result was a series of educational meetings and projects, and the emergence of shared teaching resources of which perhaps the most well-known was the original NCGIA *Core Curriculum in GIS* (Kemp and Goodchild, 1992), discussed below. Other early education projects in the UK included *GISTutor*, a pioneer computer tutorial system (Raper and Green, 1992), which, although not used by many, developed a variety of important concepts. Similarly, the ASSIST (Academic Support for Spatial Information Systems) project to develop resources for training GIS-users was funded by UK Universities' Joint Information Systems Committee (JISC) and reflected the relative ease of obtaining support for software and teaching resource development associated with almost any new technology. That not much of the substantive materials developed by these projects remain shouldn't surprise, nor, necessarily should be of concern. Technology was evolving more rapidly than the ability of the education system to produce quality materials that were both academically and technologically 'portable' between institutions, disciplines and systems.

At first some of the key issues under discussion were about what to teach, when and how to teach it. In terms of intended learning outcomes (ILOs), many instructors focused (often by necessity) on relatively low-level 'hands on', outcomes that in Bloom's (1956) taxonomy of learning behaviours in the cognitive domain encompassed *knowing*, *comprehending* and *applying* their knowledge. Through time, it has been possible for most instructors to address higher-order objectives so that students faced with problems which ask them to analyse, synthesize and evaluate possible solutions. At the same time, this has meant that some of this hands-on training has largely disappeared from the curriculum. Relatively few students are now introduced to programming in Visual Basic, C, C+, Java or even Python, but such skills and abilities can help them to better analyse, synthesize and evaluate solutions to practical and theoretical problems. So, tension remains as to how best to focus GIS&T curricula in particular educational settings. GIS&T educators have responded to such challenges in creative, innovative ways. The sections below outline some on these advances as well as our rationale for the organization of this book.

GIS&T and the academic curriculum and issues in course design

In Sections 1 and 2 of this book the focus is on one of the greatest challenges faced in GIS&T education which was to establish its place in existing university and college curricula (Chen, 1998; Gilmartin and Cowen, 1991; Jenkins, 1992; Johnson, 1996; Lloyd, 2001; Nyerges and Chrisman, 1989; Painho *et al.*, 2007; Poiker, 1985; Sui, 1995; Unwin, 1997; Unwin and Dale, 1990). This has raised practical issues developing new courses, as well as theoretical concerns about how GIS&T should be situated within undergraduate and graduate/post-graduate curricula and the rigor of this education (Marble, 1998; 1999). This situation meant that GIS&T educators have tended to be open to new ideas that would help them get started. They welcomed initiatives like the US-based NCGIA and UCGIS and in UK Regional Research Laboratories to education. Although many of the issues faced by the first innovators were different to those of today, the question of how best to fit GIS&T into the academic curriculum remains a moving target and the reason we highlight it so prominently in this book. It is an issue likely to be confronted by almost any recently developed, but reasonably distinct branch, of the academy. One of the key innovations in the GIS world was the development of prototype curriculum materials like the *Core Curriculum in GIS* published by NCGIA in 1990 (Goodchild and Kemp, 1992). As Kemp notes in her chapter, these materials helped educators develop courses in many countries (Coulson and Waters, 1991). Other projects have been aimed at two-year community colleges, such as the GISAccess project, the iGETT project and NCGIA's *Core Curriculum in GIS for Technical Programs* (Allen *et al.,* 2006).

The most recent and most externally significant effort in this direction was the publication of the *Geographic Information Science and Technology Body of Knowledge* (DiBiase *et al.*, 2006). More than a replacement for the earlier *Core Curriculum*, the *Body of Knowledge (BoK)* expands and updates the range of topics included and provides a framework for building and assessing GIS&T curricula (DiBiase *et al.,* 2006, 23–25). There are exceptions, but this is one of the very few attempts that we know of in which a discipline has attempted to formalize and publicize the knowledge that its practitioners might be expected to have, specified in terms of intended learning outcomes. The authors of the *BoK* do point out two areas where more work is needed (Dibiase *et al.,* 2006, 34–36).

First, few departments have the staff and resources to address the full scope of the *BoK*. They must make choices about the core concepts and optional topics they will cover in their curricula. Although the *BoK* suggests developing 'multiple pathways to diverse outcomes', none were developed for the first edition. Second, institutions of HE have widely different educational missions and goals and the *BoK* is not necessarily easily adapted to all of these settings. That is, justifications for GIS&T in the curriculum can vary greatly say between a small, private liberal arts BA program in the US, in which GIS&T may be stressed as a means of cultivating critical thinking and reasoning (Sinton and Lund, 2007), and a two-year college in which the employability of GIS&T graduates may be the key reason for developing GIS&T courses and curricula. In research-intensive universities (such as can be found in the UK), far different rationales are needed particularly those relating to cutting-edge scientific research. It may well be that articulation in the language of intended learning outcomes is a key step in making these transfers between sectors.

One of the most important curriculum debates revolves around establishing programs and standards for professional education and certificate programs. Both the American Society for Photogrammetric Engineering and Remote Sensing (ASPRS) and the GIS Certification Institute (GISCI) now offer successful certification programs for GIS&T professionals, with the latter leading to recognition as a Certified GIS Professional (GISP). In UK during the 1990s the Education and Research Committee of the Association for Geographic Information (AGI) introduced a formal continuing professional development scheme (Unwin *et al.*, 1995), which still runs as a voluntary service to members of the Association (see AGI, undated). This did not lead to any formal recognition, but in 2002 the Royal Geographical Society-Institute of British Geographers (RGS-IBG) and AGI collaborated to introduce a formal 'chartered' geographer qualification with a specialization in GIS&T 'CGEOG (GIS)' for which applicants had to demonstrate a past track record of work involving geography, sign up to a formal code of conduct, and commit to a program of continuing professional development (CPD). The schemes established by GISCI and AGI/RGS-IBG have been running for about the same length of time but at the time of writing in USA (pop: around 310 million) some 4,668 people are registered GISPs, whereas around a quarter of the 350 Chartered Geographers in UK (pop: 68 million) are GIS&T practitioners. Although these schemes go some way towards fulfilling the professional need, it is clear that more discussion at the national or international levels is needed to reach agreement on what a certificate in GIS&T should include. It may well be that such certification is of more value in some areas of GIS&T such as surveying, land-record and cadastral mapping, and photogrammetry, than in others, such as town planning, management and ecology, where there is pre-existing professional framework. In the UK for example, RICS maintain a certification program for courses which include various master's level programs in GIS.

Academic certificate programs are also growing rapidly in both undergraduate and graduate/postgraduate curricula (UCGIS, 2008). For example, Esri's (2009) online database lists 316 such programs internationally. The precise meaning of such certification is not always clear (Obermeyer, 1993). Wikle (1999, 54) notes that these programs are 'different from degree programs mostly in terms of their focus and duration. In contrast to degree programs that include general education courses, certificates are narrowly focused and require less time to complete'. Certificates may, however, differ little from what majors or minors would earn in a traditional degree program by concentrating some of their optional components in GIS&T, though these certificates can also be helpful in documenting a students' in-depth training as they enter the workforce or advance their careers.

Perspectives on teaching GIS&T

GIS&T educators have also been at the forefront of education innovation in other areas, and this is the theme of the third section of this volume. Perhaps the most notable is their embrace of active-learning (Carlson, 2007; Drennon, 2005; Lo *et al.*, 2002; Summerby-Murray, 2001). Active pedagogy is the umbrella term for a variety of related interrelated techniques such as problem-based learning, inquiry-based learning, discovery learning and experiential learning, all rooted in constructivist learning theory. By shifting the focus of the learning experience from the teacher to the student, the aim is to engage students as active – not passive – participants in the learning process. Active pedagogy is not the only area of innovation. Ethics education has been the focus of much recent attention as, for example, in the Ethics Education for Future Geospatial Technology Professionals project (Wright *et al.*, 2009). GIS&T is raising a number of important ethical issues such as privacy when GIS&T is used for surveillance (Fisher and Dobson, 2003) or when data collated by location is used to create profiles such as those used in geodemographics (Crampton, 1995). The use of GIS&T in decision making may lead to harm to people, places and the environment if, for example, data are misused or if erroneous data find their way into use. The widespread use of costly and complex GIS&T can also accentuate the digital divide by limiting access nations, organizations, or individuals who lack the resources to acquire GIS&T. It is likely that these issues will gradually become more prominent in curricula in future years.

Of increasing interest is how GIS&T is being integrated into curricula outside geography and the environmental sciences. Sinton and Lund (2007) overview a range of such examples in the social and natural sciences, but more attention should be devoted to helping educators in these disciplines get started with GIS&T. The Center for Spatially Integrated Social Science (CSISS) in the US and the *Spatial Literacy in Teaching* (SPLINT) CETL in the UK are examples of initiatives which adopted strategies to aid such transfer to other disciplines but much remains to be done.

Digital worlds and teaching GIS&T

The fourth section of this book focuses on how recent innovations such as virtual globes, *Second Life*, and mobile technologies are enriching GIS&T and how educators can make use of such developments. Virtual globes like *Google Earth* and NASA's *World Wind* are providing new methods for the delivery of GIS&T to a wider audience which includes a broader range of academic disciplines and courses. Although map server technologies have advanced very quickly, recent systems like Google Earth, Virtual Earth and ArcGIS Explorer provide online excellent visualization tools and intuitive interfaces which are easier for new users to navigate. Furthermore, the open application programming interfaces (API) of recent systems like Google Earth and Google Maps have made it much easier for users to create custom maps, opening up a world of 'mashups' in which users can overlay their own data on existing maps. They do not offer all of the analytic capabilities of GIS or visualization capabilities of CAVEs and similar high-end expensive VR systems, but have instead helped spur the rise of a neogeography movement reflecting Goodchild's 'democratization of GIS': the use of geographic and spatial data by non-expert users, the rise of user-generated geospatial content, and efforts to use 'crowd sourced' information effectively. All of these developments suggest new directions in which GIS&T education can move so that mashups and virtual globes can support learning both inside and outside geography. Again GIS&T educators have taken the lead in exploring, at least tentatively, the use of virtual worlds and other new internet and virtual reality techniques (Hudson-Smith and Crooks, 2008) in education. Even *Facebook* and *Second Life* sites have been used to promote interactions between teachers and learners (DeMers, 2010; 2011; in press).