

A Self-Learning Multimedia Approach for Enriching GIS Education

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Geographic information systems (GIS) are a rapidly evolving technology ABSTRACT that has recently been integrated into undergraduate and postgraduate learning. GIS is also a multidisciplinary technology that has important relevance beyond its traditional disciplinary homes. This paper describes an initiative developed by the Department of Geomatics at the University of Melbourne, Australia, to create multimedia-based self-learning modules for teaching GIS to undergraduate and postgraduate students. The modules are designed to complement rather than replace existing approaches to learning such as formal lectures, practical laboratory assignments and major project requirements. The learning modules have been developed using Macromedia Director and are delivered interactively via the Internet. This paper examines the pedagogical issues of learning that accompany technological advancement and practical issues of module development. It discusses results from preliminary student evaluations and examines the broader learning opportunities associated with flexible delivery mechanisms such as the Internet. Further details and access to all modules are available at http:// www.geom.unimelb.edu.au/gisweb/

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Introduction

A geographic information system (GIS) is a computer-based system for managing, storing, analysing, modelling and visualising spatial information. The precursor to current GIS was software developed for automated cartography. However, in the past decade GIS has evolved beyond simple automated mapping into the realm of analysis, modelling and spatially explicit decision support. Some would say that in combination with the technical developments associated with GIS, we have also witnessed the

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emergence of a new discipline called geographical information science (Goodchild, 1992). GIS is a rapidly evolving technology and was included in undergraduate programmes at the University of Melbourne, Australia, for the first time in 1990. Because GIS is a technology based on dynamic spatial concepts, it lends itself well to multimedia-based representations and learning. However, these dynamic concepts are also difficult to illustrate in static textbooks and lecture notes. GIS software, while itself dynamic, shields the user from the intricacies of the spatial algorithms that are the key to any analysis. A GIS education therefore requires quite different strategies from GIS training.

From an educational perspective, GIS attracts students from a diversity of disciplines including geomatics, computer science, archaeology, geography, architecture and earth science. As such, the GIS curriculum is particularly suited to the development of innovative learning models adaptable to students from different disciplinary backgrounds. From the perspective of technological innovation, a GIS curriculum is also ideally suited to transformation using novel technologies as the discipline itself is technologically enabled, or even technologically driven. Hill and Solem (1998, p. 106) note that the inherent technological emphasis of GIS educators places them in an excellent position to "make a paradigm shift from the didacticism of the traditional lecture hall to the technology-rich, constructivist environment partly by encouraging many local experiments in teaching practice with information rich technologies". This paper describes one way to adopt a constructivist approach to GIS learning.

The Internet-based GIS multimedia self-learning tools described here aim to enhance rather than replace traditional GIS learning models such as lectures, tutorials and practical assignments. A suite of modules has been integrated into existing curricula. The modules include theory, worked examples and self-paced revision tests. They cover core concepts identified by academic staff where students have experienced difficulties without specific visual or interactive support. Sui and Bednarz (1999) state that new communication media should not simply replace older ones because each medium plays a unique role in shaping human consciousness and social development. They stress 'the continued need for books and face-to-face human interaction in the educational process, especially when we consider the inherent multiple intelligences possessed by each individual' (Sui & Bednarz, 1999, p. 96). In other words, students have varying learning needs and hence they respond differently to different delivery models. The initiative is unique in that it integrates Internet-based delivery, multimedia and core learning concepts to complement existing learning models.

In contrast with the proliferation of Internet-enabled communication tools including virtual discussion groups/forums (Ludwig, 1999), online tutorials and field trips (Crampton, 1999), email distribution lists and video conferencing (Deadman et al., 2000), this initiative aimed to develop an interactive multimedia model for learning. The multimedia approach, which has a high degree of interaction, has confirmed the value of such models although additional evaluation is nevertheless required. The multimedia self-learning approach is expected to have widespread utility for undergraduate and postgraduate students at the University of Melbourne and internationally. The learning modules are freely available over the Internet to educational institutions or individuals. The modules are considered 'freeware' in an effort to extend the benefits beyond the University of Melbourne. A key factor in the success of this multimedia initiative is the IT and technological literacy of academic staff in disciplines such as geographical information science. Solem (2000) examined this issue of differential adoption of Internet-based teaching practices amongst academic staff. It was found that an academic's research

specialism was closely related to his/her perception, adoption and practice of Internet-based teaching. Pragmatic factors such as access to multimedia funding sources, access to computing technology and previous experience with curriculum transformation will also determine the success of such an initiative.

The University of Melbourne's Multimedia Learning Initiative

The University of Melbourne's strategic plan aims to transform teaching in all courses by the appropriate use of multimedia and educational technology. This initiative is driven by pragmatic concerns such as the pressure to attract more and better students, to improve the employability of graduates with new technologies and to foster motivations such as improving the quality of learning. Hill and Solem (1998) examine the recent pressures upon academia to adapt to new technology-based learning models. At the University of Melbourne, an internally competitive initiative has been the allocation of funds for the transformation of units and courses (http://ditam.meu.unimelb.edu.au), and both phases of this project were funded by a university Teaching and Learning (Multimedia and Educational Technology) Committee grant.

In the first instance a priming grant was provided to develop core modules and, based on the success of these, additional funding was provided to further develop the project. From an innovation perspective, this GIS self-learning initiative is relatively different from other efforts to transform curricula with the assistance of information technology. For instance, many of the earlier examples including Rich *et al.* (2000) and Ritter and Lemke (2000) have focused on issues of communication and collaborative learning via the Internet with lesser emphasis on multimedia approaches. Hurley *et al.* (1999) have labelled such approaches to learning 'collaborative distance enquiries'. Hardwick (2000) notes that the shift towards collaborative models also removes the common *competitive paradigm* inherent in education. This project makes little effort to develop a collaborative interaction environment as the focus is on self-paced individual learning.

The Internet and Multimedia as a Learning Tool

Multimedia is becoming increasingly important to the future of education. With the proliferation of digital technology and the Internet, educational environments are evolving to provide alternative delivery methods and web-based instruction. There is little doubt that the proliferation of the Internet and the rapid improvements in usability and interaction have generated both excitement and trepidation in academia. Owston (1997, p. 27 in Hurley et al., 1998) notes that "nothing before has captured the imagination and interest of educators simultaneously around the globe more than the World Wide Web. The web is now causing educators from preschool to graduate school, to rethink the very nature of teaching, learning and schooling". Importantly for educational institutions, the proliferation of the Internet has globalised the access to learning material. This is both a strength and a threat to existing learning models and educational institutions. Students can access an array of material to compliment their learning, while the geographic boundaries can be broken down and the inadequacy of existing learning models becomes more apparent. Marion and Hacking (1998) examined the relative merits of the Internet in education. They identified a number of limitations of printed material including the fact that it can become rapidly outdated, lacks interactivity, and most importantly for this study, it is difficult to portray dynamic concepts such as spatial algorithms. Bearing these limitations in mind, Marion and Hacking (1998) recognise that

books offer an improved level of convenience and longer term durability, although the latter issue is yet to be determined in the context of the Internet. They also recognise that the evolution of the Internet has the capability to build a more constructivist environment to learning. Roblyer *et al.* (1997, p. 72) identify constructivist learning environments as those that:

- involve problem-solving activities;
- provide visual formats and mental models of the problems to be solved;
- provide rich learning environments;
- involve cooperative or collaborative group learning;
- promote learning through exploration;
- utilise authentic assessment methods.

Although a shift to constructivist approaches to learning is often sought, Hurley *et al.* (1998) caution that instructivist approaches are nevertheless valuable. For instance, constructivist approaches assume prior knowledge, they stress breadth over depth and are inherently difficult to assess. Additional research is required to determine how such models can be adopted for GIS focused learning. A key aim of our project is to evaluate the extent to which the learning objectives are indeed being met using semi-structured interviews and questionnaires with postgraduate and undergraduate students.

GIS and Multimedia Learning

The traditional model of GIS learning has been based on the formal lecture/practical assignment/project model. During the late 1980s, however, educators began to examine using multimedia-based methods to extend the existing and limited range of learning tools. The spatial nature of geographical analysis which is so critical to GIS, combined with recent advances in computing technology, makes multimedia an ideal environment for learning GIS concepts. Two examples of these early multimedia-based GIS education tools were ARCDEMO (1987) and GISTutor (1989). More recently the Environmental Systems Research Institute has established its Virtual Campus for GIS learning (http:// campus.esri.com/). However, this initiative is far from interactive and simply delivers existing curricula via a hyper-linked Internet delivery mechanism. This approach is not uncommon where curriculum transformation implies Internet delivery of existing and non-flexible material. Other initiatives include the NCGIA core curriculum (http:// www.ncgia.ucsb.edu/pubs/core.html) and the University of Texas Virtual Geography Department (http://www.Colorado.EDU/geography/virtdept/contents.html). These initiatives can be best described as Internet-based clearinghouses and curriculum development projects. It is interesting to note that the early and innovative multimedia approaches including ARCDEMO and GISTutor have remained relatively dormant since the ascendancy of the Internet and efforts have been devoted to developing collaborative environments and information portals. This delay in the move towards an interactive self-learning model may be due to the rate of technology diffusion associated with the Internet. A key objective of the University of Melbourne initiative was to avoid this delivery model for learning, and develop true multimedia interactivity.

GIS Curriculum Overview

In the Department of Geomatics the majority of undergraduate students are completing combined degrees with their other streams as diverse as computer science, earth science and the humanities. They have very different strengths and interests in quantitative and computational methods. The GIS curriculum is taught in all four undergraduate years beginning with introductory material and extending to problem-based major group projects and GIS macro programming and model development. In addition to the undergraduate cohort, the nature of postgraduate GIS education in the department is ideally suited to use the same multimedia materials. Owing the multidisciplinary nature of the science, postgraduate students have diverse backgrounds with little or no prior GIS knowledge, and these subjects are often their first exposure to key concepts. For example, the three main postgraduate courses—including (1) the Master of Applied Science in GIS (coursework), (2) the Graduate Diploma in GIS and (3) the Graduate Certificate in GIS—all introduce students to relatively elementary GIS analysis concepts that have been addressed in the multimedia learning modules. Hence, the multimedia learning initiative has a relatively large and broad audience across the university, which raises a number of challenges in both the development of the product and its ongoing use.

Multimedia Software Adoption

After extensive consultation with staff from the University of Melbourne's Multimedia Education Unit and other staff involved in interactive multimedia development, a decision was made to use Macromedia Director, Flash and Shockwave combined with HTML and Java scripts. Macromedia Director movies are delivered via the Internet using Shockwave movies via a plug-in installed on the client computer. The combination of Macromedia Director and Flash has proved very successful as the products have rapidly evolved into industry standards and are relatively ubiquitous. There are distinct advantages in using an Internet browser as the delivery mechanism. In the first instance, the multimedia modules are software and hardware independent which provides important delivery flexibility. Second, the Shockwave plug-in required by Internet browsers is freely available making it suitable for educational use. And finally, Internet-based delivery, as opposed to other mechanisms such as CDROM, means the modules can become rapidly accessible to a local and international audience, and changes and updates are made instantly available. However, the main limitation with our approach is the bandwidth limitations inherent in transferring Shockwave movies over the Internet using modems and telephone lines. For example, some Shockwave movies are often in excess of 1.5 megabytes in file size. Within the university and between sites that have broadband or fibre-optic Internet access, these file sizes are rarely a problem.

GIS Multimedia Self-Learning Tool: description and core content

Most GIS textbooks follow a typology for introducing and discussing core GIS content. For example, the commonly used raster and vector typology subdivides the learning of GIS core concepts into two distinct categories based on the spatial data structure. Such an approach commonly introduces a chapter on primary data capture including digitising and the role of satellite imagery and aerial photography. Other textbooks introduce a typology based on distinct application areas (Haines-Young *et al.*, 1993). Tomlin (1990) focuses entirely on raster analysis by partitioning the book chapters according to the type of spatial operator being described. For instance, one chapter examines multi-layer spatial operations while another examines single-layer operations. Other textbooks such as Burrough and McDonnell (1998) have moved beyond the data entry, database creation

and spatial overlay model to examine more contemporary issues such as error modelling, interpolation and broader non-technical GIS implementation issues. This recent shift is expected since GIS, as a technology, has progressively moved away from the automated cartography paradigm to a modelling and analysis emphasis.

The choice of the core content for the development of multimedia learning tools was a key component of the project. It was decided that the focus of this initiative should be on core GIS concepts with a particular emphasis on spatial algorithms. The reasons for these choices are threefold. First, the chosen modules are those that commonly form the basis of elementary GIS learning. Second, many of the selected modules address spatial concepts that students commonly have problems understanding. And third, owing to the financial and time commitment to the project an aim was to maximise the possible longevity of the core content.

Another characteristic of the developed product is that GIS concepts are taught generically rather than within the constraints of the chosen GIS software. This is a major limitation associated with entrenching learning on pre-defined software models. It also places an unnecessary, and often limiting, reliance on proprietary software for learning. The hyperlink metaphor of multimedia and the Internet has an important strength in that distinct and structured typologies are not necessarily required to build a learning tool, as is the case for textbooks and lecture notes. Hardwick (2000) labels these existing models 'linear' approaches to learning. A key aim of this initiative is to adopt this hyperlink metaphor and to present the modules as a 'toolbox' to be integrated into learning, and in no particular or predefined order. Although this section discusses the initiative in terms of modules, the final product is a suite of tools that can be selected and pieced together by academics and students alike. In practice, academics utilise the Algorithm demonstration component of the modules in a formal lecture environment. This provides the lecturer with a dynamic visualisation tool in real time. Students are then referred to the Theory and Interactive Examples and are encouraged to explore these modules in further detail during computer-based practical classes, and in their own time. As the GISWEB project contains no formal assessment, a traditional exam is generally used at the conclusion of the semester, where exam questions and concepts are based on core issues derived from GISWEB. Figure 1 shows the GIS Self-learning Tool and its various modules that are accessible via this portal (www.geom.unimelb.edu.au/gisweb/).

The modules broadly come under the following titles:

- Introduction to geographic information systems;
- Vector overlay processes;
- Raster analysis;
- Terrain analysis;
- Spatial data entry;
- Neighbourhood operations;
- Buffers;
- Line generalisation algorithms.

In addition to these core modules, the site contains an extensive GIS glossary, a suite of GIS references, a site map to aid navigation and a user feedback form. All modules follow a similar structure including theory, algorithms, interactive examples and a student test. The theory included in each of the eight modules can be downloaded as a Microsoft Word file. This allows students to cut and paste the theoretical material to create their own notes as required. Some of the advantages of multimedia-based models



The Geographic Information Systems self learning tool has been developed to enhance teaching of GIS in the Department of Geomatics. The modules cover a range of subjects that expose students to both introductory and advanced concepts in GIS.

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FIGURE 1. Internet portal for the GIS self-learning tool.

of learning in comparison with traditional modes such as textbooks that were described earlier are examined in detail below.

Animations

Shockwave movies have been incorporated in order to visualise, step by step, the operations performed by each of the algorithms described in the module. Figure 2 provides an example where a movie demonstrates how the circle (neighbourhood) moves across the raster image to calculate values of the central cell based on the neighbouring values.

Interactivity

Varying levels of interactivity have been incorporated in all modules in an attempt to provide the user with control over the algorithm. In the example shown in Figure 3, the user can choose amongst different options for setting distance tolerances and the 'look ahead value' used in a GIS to generalise line features. Depending on the user choice, an interactive display shows the resultant line generalisation in real time.

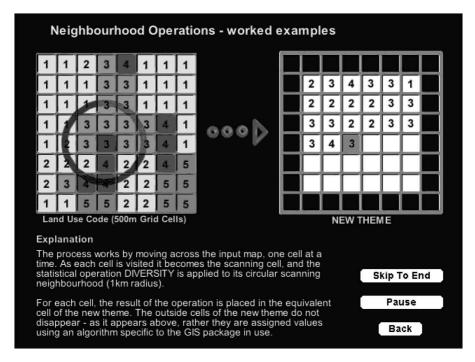


FIGURE 2. Animation for neighbourhood operations.

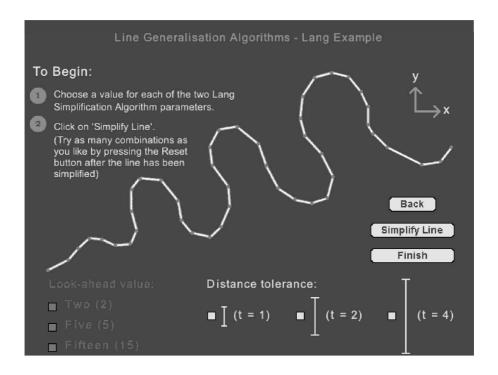
Self-learning Feedback

Student feedback is provided at the completion of each module via an online test. This allows students to evaluate their understanding of each lesson and provides a justification for the answers given. In the example shown in Figure 4 the user has requested feedback with regard to the answer provided to Question 4. The feedback provides an explanation and justification of all the possible answers.

Capturing Student Feedback and Evaluation

Central to any multimedia learning initiative is the evaluation phase. This phase can be subdivided into three different but complementary sections. First, the evaluation of the product itself and the determination of whether objectives have been achieved. Second, the evaluation of learning outcomes and the comparison between both methods, traditional and multimedia, in the teaching of GIS. Finally, personal evaluation undertaken by the researchers involved in the project and in the teaching of GIS subjects. The only evaluation we are able to conduct at this stage is the first one although some comments on authors' anecdotal evidence are also provided at the end of this section. Until further evaluations become available, many of the curriculum transformations we have witnessed may simply be viewed as experiments in technological innovation rather than as mechanisms for improved learning. Sui and Bednarz (1999) succinctly framed this problem noting that with technological innovation often 'the message is the medium'. The following discussion examines the broader responses from students who have already used the system.

The responses from the feedback are presented in detail in Table I as they highlight



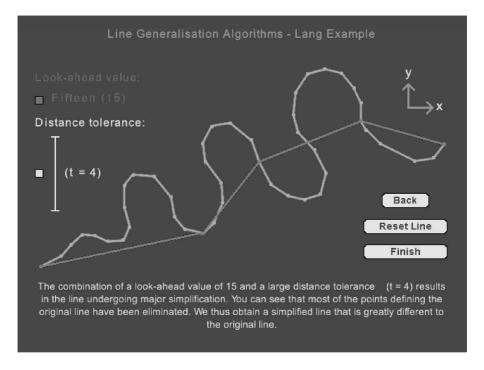


FIGURE 3. Interactivity available in the line generalisation module.

		Terrain Analysis - Answers
question 1question 2question 3question 4question 5	0 0 1 1	Question 4 The slope of slope map can provide important information. On a slope of slope map: * high values indicate rough terrain CORRECT high values indicate a sudden change of slope; this may happen in rough terrain
question 6 question 7 question 8	1 0	* a zero value means that the area is flat INCORRECT a zero value simply means that the slope is not changing, this might be along an incline
total	4	* the highest values indicate the areas of steepest slope INCORRECT the highest values are where the steep slope changes most rapidly, these are not necessarily the steepest areas
exit test		* areas of convex or concave curvature can easily be distinguished from each other CORRECT

FIGURE 4. Student feedback provided after the self-learning quiz has been answered in the terrain analysis module.

the key issues, observations and conclusions that could guide future module development. In addition, the lessons learnt may act as a guide for other multimedia-based GIS learning initiatives. Another section of the feedback form involved students providing written responses to questions. These comments proved to be the most useful aids for determining the utility of the modules and the broader project aims. The main responses and suggestions provided by students are described below and in Table I:

- Students valued the provision of theory material in Word format as it allows them to make additions, and further build-up a tailored learning resource.
- There was a general need for more flexible navigation so that particular sections could be bypassed for more experienced users. The hyperlink metaphor creates design challenges as from an educational perspective, and it may be desirable to direct students through a module rather than by providing 'outs'.
- A common observation was that the time required to download shockwave animations
 was excessive and a major limitation in the work. Owing to this, we have permitted
 some educational institutions to mirror the GISWEB site locally and some students
 have been provided with CD-ROM versions.
- For a number of pages, not all the information could be seen on the screen at the same time, requiring the user to continually scroll and lose track of his/her starting points. This is likely to be a common limitation of many multimedia-based projects that require a computer terminal as the display interface.

The GISWEB initiative is currently in the maintenance stage and is being used actively at the University of Melbourne and internationally. Non-invasive web usage statistics have recently been compiled indicating the global success of the project. These are providing key summary indicators including module use and popularity, module interaction and duration, within-module travel and user geographies (obtained from user domain addresses). Table I provides a summary of the top eight client access points ranked by data volume transferred and shown by geography (captured on 1 May 2001). Interestingly, Saturday-use figures are quite similar to midweek traffic, indicating that

TABLE I. Summary of student responses for the neighbourhood operations module.

			Response (%)				
Questions		AS	A	N	D	DS	
1.	The instructions to use the Neighbourhood Operations site were clear	50	50	0	0	0	
2.	The web pages were easy to navigate	39	61	0	0	0	
3.	General layout/design of Neighbourhood Operations site was well organised	33	61	6	0	0	
4.	The textual information effectively conveyed the concepts and applications of Neighbourhood Operations	28	56	6	11	0	
5.	Graphics and animations were effective in illustrating the concepts and applications of Neighbourhood Operations	44	50	6	0	0	
6.	Interactivity (user control) was useful for learning the concepts and applications of Neighbourhood Operations	56	39	6	0	0	
7.	The 'Questions with Feedback' component was adequate for testing concepts	33	61	6	0	0	
8.	The instructions and use of the interactive lessons were clear	39	61	0	0	0	
9.	Time needed to load the Shockwave movies (lessons) was acceptable	6	39	44	11	0	
10.	The level of detail in the lessons was adequate	6	78	17	0	0	
11.	The level of control over the interactive lessons was adequate	33	67	0	0	0	
12.	These web pages would help my understanding of Neighbourhood Operations	28	72	0	0	0	

KEY

Notes: Agree Strongly (AS); Agree (A); Neutral (N); Disagree (D); Disagree Strongly (DS). Source: After Nascarella and Urquhart (1999).

people may be commonly using the modules from home (bearing in mind that most users are from Australian domains). The average visitation time in April was about 10 minutes and each user views approximately 12.6 pages. Very similar visitation statistics occur for the other months for which we have been logging use. We suspect, however, that these relatively low means are skewed by outliers who are only 'surfing' the Internet for GIS resources, rather than using the site for learning. [Real-time Internet statistics for this initiative are available at http://www.geom.unimelb.edu.au/weblog/gisweb/log.html]

Although these indicators provide a quantitative estimate of site use, the missing ingredient remains a thorough evaluation of learning outcomes. Based on informal discussions with current users, both students and academic colleagues, this initiative has proved quite successful. The GISWEB self-learning tool certainly facilitates the lecturer's task in the formal lectures. It helps to demonstrate dynamic concepts and algorithms and provides a more visually attractive complement to the theoretical explanations. Students appreciate this initiative as an excellent and innovative learning tool. As expected, it also allows them to review the concepts explained in the lecture

TABLE II. Recent and non-invasive web-usage statistics summary for top-eight client geographic locations (May 2001).

Rank	Country/domain	Hits	Bytes
1	Australia	2934	27 950 328
2	United Kingdom	271	1 280 660
3	US Educational	59	716 598
4	Hong Kong	55	375 230
5	US Commercial	29	188 671
6	Germany	13	91 995
7	Singapore	6	42 609
8	Non-profit	8	36 317

theatre at their own pace. Although these advantages are acknowledged, some problems have also been detected. Students commonly complain about the speed with which the required Shockwave movies are downloaded. Lecturers have also noticed that many students do not voluntarily access this kind of learning material. This is not unlike a student's reluctance to access recommended reading and hence the multimedia approach in itself may not be enough to generate greater student usage and interaction. One possible solution is to integrate these modules into the formal subject assessment, although this moves away from the focus on constructivist learning.

Conclusions

The development of a multimedia initiative to complement GIS learning can adopt a number of technical approaches. It can include various levels of user interactivity and simulation, it can contain online assessment or be based around a problem-based learning principle. For GIS practitioners developing these new approaches to learning, an early choice to be made is whether the multimedia approach should follow a constructivist or behaviourist model (or a combination of both?). Until further evaluation results become available, the educational value of these models remains uncertain. However, in the early stage of development a key ingredient for success is the technical proficiency of academics developing content and guiding the curriculum transformation. Solem (2000, p. 219) notes that "innovation diffusion research has shown that users of innovations have identifiable characteristics that can be used to differentiate them from non-users". By the nature of their discipline, GIS practitioners are in an excellent position to develop such innovative multimedia learning approaches as they fall into the 'user' category deemed critical for success.

Some words of caution for others hoping to integrate the Internet and multimedia technology into learning are nevertheless required. First, such initiatives are relatively expensive as an experienced multimedia programmer is critical for the project. If the programmer is familiar with the discipline and the content provided by academics, the initiative is more likely to be successful. Second, the importance of content development and provision by academic staff cannot be overlooked. This requires a major time commitment on behalf of the academic staff involved in the initiative. Finally, the ongoing maintenance of the site requires continual resources, including the demand on staff time to carry out detailed evaluations and ongoing IT support.

In summary, the intended outcome of this project of integrating multimedia learning

into existing curricula is a self-paced student learning model that is tightly integrated with practical exercises and theory-focused lectures and tutorials. This project highlights the potential to achieve these goals, and results from student feedback indicate the utility of multimedia approaches to GIS education. Ongoing evaluation will also examine the learning objectives and outcomes from different student cohorts, including comparisons between postgraduate/undergraduate and local/international students. The authors recognise that these cohorts will have different learning needs and different rates of technological uptake. The development of multimedia-based learning to support a GIS curriculum has the scope to improve both the quality and ease of learning. This project represents one small step to utilising these technological advancements to reinvent, and also complement, traditional models of learning.

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