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Europe and the United States: the implementation of geographic information systems in secondary education in two contexts

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Since its inception in the early 1990s, geographic information science and its related technology, geographic information systems (GIS), have diffused slowly into select groups of K-12 classrooms worldwide. The technology has not been adopted at a rate commensurate with expectations. The purpose of this article is to explore GIS implementation by comparing the variable status of GIS education in pre-collegiate education in the United States and Europe and factors that appear to play a role in diffusion. The authors use a model of internal and external factors that influence adoption of education innovation as a heuristic to compare and draw conclusions.

Introduction

Geographic information science (GIScience) and its related technology, geographic information systems (GIS), currently present geography education one of its greatest opportunities—and its greatest challenges (Houtsonen, 2003, p. 57). GIS/GIScience is an opportunity for geography education because as a sophisticated mapping system and tool for spatial analysis, it has the potential to progress traditional school-based geography and spatial problem solving. The capability of GIS to incorporate numerous data-sets as mapped layers and to display these quickly and efficiently may help students to visualize relationships between and among spatial phenomena (Stoltman & De Chano, 2003, p. 132). It has the added ability to simultaneously analyze multiple layers of spatial information. GIS technology can be an invaluable resource for extending student learning when a proper instructional framework is provided in the content area, along with data analysis and spatial reasoning concepts (Baker &

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White, 2003; van der Schee, 2003). GIS is undoubtedly a powerful tool for geographic analysis and a valuable resource to teach geography and spatial thinking.

The challenge of GIS to geography educators, however, is evident in its slow adoption. Although the number of people using GIS in modern society is growing fast, the technology has not been adopted by educators at a rate commensurate with expectations. Since its inception as a desktop application for professionals in a wide range of occupations in the early 1990s, GIS has diffused slowly in educational contexts worldwide and then, largely only into select elite primary and secondary classrooms.

Geography educators have justified GIS's introduction using three competing and yet complementary rationales that correspond to GIS's strengths as just outlined: (1) the educative rationale: GIScience and GIS support the teaching and learning of geography; 2) the place-based rationale: GIS is the ideal tool to use to study geographical problems at a range of scales; and 3) the workplace rationale: GIS is an essential tool for knowledge workers in the twenty-first century. These arguments have not appealed to large numbers of teachers however.

The purpose of this article is to explore GIS implementation by comparing the variable status of GIS education in pre-collegiate education in the United States and Europe—particularly in the Netherlands—and to identify factors that appear to play a role in diffusion. It is a first step in understanding why GIS has not been more widely adopted. The article is organized into three sections. The first section, 'Lessons not learned', begins with an overview of GIS implementation and briefly portrays the status of GIS education in the United States, describing the strategies used to disseminate it into pre-collegiate education, and potential barriers to implementation. This is contrasted with initial efforts to introduce GIS in the Netherlands. Teachers' attitudes toward GIS and educational innovation are reviewed based on surveys of teachers in the Netherlands, seven nations in Europe and previous survey research in the United States. The second section, 'Understanding why', introduces a theoretical model of internal and external factors that influence adoption of education innovation. The model is applied to GIS to seek deeper understanding of the reasons why this promising technology has failed to diffuse more rapidly. We suggest that a cognitive approach to viewing how teachers develop their understanding of an innovation like GIS may be useful in developing effective diffusion and implementation strategies. In the third and final section, 'Lessons learned', we analyze the survey results using the model framework to draw conclusions about the factors impeding GIS education and to suggest positive strategies that may advance the adoption process.

Lessons not learned

The status of GIS implementation

The prevailing 'cartographic culture' in schools in both the USA, the United Kingdom (UK) and other parts of Europe remains robustly pre-GIS (Wiegand, 2004). In the UK, pioneering efforts to introduce GIS in schools led by geographers such as

Unwin (1992) and Rhind (1993) met with some success but with no great enthusiasm (Green, 2001). Reforms of the National Curriculum in the early 1990s encouraged mapping and information technology and the use of GIS addressed GCSE and A level syllabus requirements (Gill & Roberts, 2001).[1] Projects such as the Geographical Association Land Use UK 1996 survey provided a further boost. A special educational software, *AEGIS*, was developed for school use on low-power computers and the Ordnance Survey has provided data. Several articles in *Teaching Geography*, the journal of the UK Geographical Association, have provided teachers with information about GIS and education. Freeman *et al.* (1993) wrote an article, 'Getting started with GIS'. Strikingly, 10 years later Broad (2003) used the same title for an article in *Teaching Geography*. In that year Freeman (2003), writing in the same journal, indicated that 'although the use of sophisticated GIS is mainstream in industry and the public sector, its use in schools is not as extensive' (p. 38). Progress in GIS in geography in the UK was not as rapid as its advocates had hoped for 10 years earlier.

The slow diffusion of GIS is perplexing and needs to be understood in light of the opportunities this innovation offers to geography education. Attempts to explain the situation in the United States, UK and elsewhere have identified a number of nontrivial barriers to implementation (Bednarz & Ludwig, 1997). Key constraints include unequal access to hardware and software, the need for pre-processed data, and technical support. According to Wiegand (2001) and Johansson and Kaivola (2004), one of the major constraints for introducing GIS in schools in the UK and Finland has been the difficulty of obtaining appropriate base maps and databases. The same problem exists in the Netherlands and Belgium. Education-related barriers include teachers' time, training in the technology, institutional support, and didactic issues related to curriculum, instruction and assessment (Alibrandi, 2001).

Many of these impediments are not unique to GIS. Research on the implementation of technology in general reveals that there is little fundamental understanding of the role of educators in using technology to help students learn. It is clear that generic technological literacy is necessary but not sufficient to implement technology in schools. It is also clear that there is little support to guide educators to integrate technology to teach specific content (Wallace, 2004). There has also been a paucity of research concerning the ways the GIS environment supports or undermines teachers' geography instruction.

GIS in the United States

In his seminal study on the status of GIS in the United States, Kerski conducted a national survey of educators in the 1520 high schools that had purchased GIS software by 2000. These high schools represent less than 8% of the estimated 19,998 public and private high schools in the United States (Council of Chief State School Officers, 2001). He found that only half of the educators who owned the software were using it and of that number, a mere 20% used it in more than one lesson in more than one class. His other findings included that teachers think the software is complex, they lack time to develop curriculum to use GIS, and they have little technical and instructional support (Kerski, 2003). GIS's failure to be widely adopted in classrooms in the United States may be attributed to teacher training (Bednarz & Audet, 1999) and to inadequate research on its effectiveness in promoting significant learning in geography and science (Baker & Bednarz, 2003).

Teacher education is key in the US context. Because of teacher preparation methods oriented toward preparing broadly educated social studies teachers and state certification requirements, there are very few well-trained, specialist geography teachers with substantial coursework in the subject. Although no studies have quantified this, it is apparent that many educators with the responsibility for teaching geography do not have an understanding of the spatial perspective that is key to geography. This lack of specialist geography teachers means that many teachers have limited *pedagogical content knowledge*, defined as knowledge about the best way to teach subject matter. The result is that few teachers assigned to teach geography recognize the potential opportunities GIS offers to teach geography content and skills.

A lack of adequate curriculum materials further impedes adoption by US teachers. Research on the first summer GIS training conducted by ESRI for teachers in 1998 indicated that even pioneer teachers who understood GIS and had sophisticated geographic pedagogical content knowledge had a difficult time finding ways to incorporate GIS into their curriculum (Bednarz, 2004). The introduction of a GIS-based regional geography textbook, *Mapping Our World* (Malone *et al.*, 2002), provided geography teachers with the support many needed to begin using GIS, jumpstarting use by interested, non-pioneer teachers (Kerski, 2003).

An additional factor impeding widespread adoption of GIS in the USA may be the strategies used to disseminate it into pre-collegiate education. Because of the decentralized nature of the US education system, no concerted national plan has been developed to coordinate efforts. GIS vender ESRI has probably had the largest impact on K-12 (i.e. compulsory) education working through the existing network of state geography alliances and professional organizations such as the National Council for Geographic Education. By widely distributing *ArcVoyager*, a simplified, teacher-friendly GIS software, thousands of educators have at least been introduced to and made aware of GIS. In 1998, ESRI, in collaboration with several universities and institutions, initiated a series of intensive summer training institutes to create a cadre of highly motivated and expert GIS-literate teachers (www.esri.com/industries/k-12/education/trainers.html). These teachers have trained many more educators following a training-of-trainers model. Nonetheless, the scale of such efforts has not been sufficient to reach a critical mass of educators. GIS remains the domain of a small number of geography teachers.

GIS in the Netherlands

Although GIS is widely used in business, administration and higher education in the Netherlands it was largely ignored in education until the end of 2003. Early attempts to introduce GIS in secondary education in the Netherlands failed for some but not all of the same reasons mentioned for the United States. One of the main barriers to implementation was the availability of data and software. In contrast with the situation in the USA, Dutch schools had to pay for data. Most of them could not afford big investments in GIS software, and the Netherlands did not have a GIS vender willing to distribute software at low or no cost. In addition and probably more importantly, without effective examples of the use of GIS in education, Dutch teachers were not inclined to implement GIS. So while GIS was being introduced in education in the USA, slowly and somewhat unsuccessfully, GIS went unnoticed for a decade in the Netherlands.

Conditions changed with a reform in the curriculum that removed several technical barriers. The new Dutch secondary curriculum prescribes a great deal of research work, and students and educators have become more interested in ways GIS can support this new focus. A study of the environment of the local community is a popular theme among geography students. In addition to conducting fieldwork, students carrying out such studies interact with public agencies and local government authorities to obtain spatial information to support their studies. The Dutch Land Survey Office in particular was inundated with requests for spatial information especially about land use. As a result of this interest in local communities studies, the Land Survey Office took the lead to create EduGIS, a GIS portal designed for use by secondary education (www.edugis.nl) launched on Education Day, November 2004 with the approval of the Royal Dutch Geography Society. This portal offers digital maps, materials about GIS and its functions, and geography curriculum materials that use GIS.

In light of these curricular changes, during autumn 2003 a questionnaire was sent to 200 geography teachers in the Netherlands to assess geography teachers' opinions about GIS (Korevaar & van der Schee, 2004). The names and addresses came from various lists of geography teachers that had participated in geography in-service training sessions during the last three years. Seventy-three surveys were returned, a credible 37% response rate. All respondents were geography teachers in secondary education. More than 65% of the respondents had more than 15 years' experience in geography teaching, 50% were 50 years or older and 60% of the respondents reported using their computer every day.

Some remarkable results from the questionnaire are:

- 12% used GIS in their geography classes;
- 81% said that there should be more GIS in geography teaching;
- 40% of the geography teachers said that GIS should be compulsory in geography teaching;
- 87% said that they would attend in-service training about GIS in geography teaching if organized;
- geography teachers who used their home computer often were significantly better in producing examples of the use of GIS in daily life than geography teachers who used their home computer less often (one-way ANOVA $F(3,68) = 3.26$, $p = < .05$);
- the group of geography teachers who let their students use digital maps to compare different maps of one area were significantly more positive when answering the

question about whether GIS should be compulsory in geography education (one-way ANOVA $F (1,34) = 4.35$, $p < .05$) than geography teachers who did not.

- The main arguments mentioned by Dutch geography teachers (n = 64) for why they did not use GIS in their lessons were: 31% lacked good hardware; 39% lacked knowledge.

Although the group of Dutch teachers that responded to this questionnaire may be more GIS oriented than the teachers that did not respond, the investigation revealed some unexpected results. While a minority of Dutch geography teachers use GIS in geography teaching, the majority would prefer to do more with GIS. A remarkable 40% of respondents wish to introduce GIS as a compulsory element in the curriculum indicating that this sample of Dutch geography teachers see the importance of GIS in geography teaching. The main impediments to introducing GIS in Dutch geography classrooms are hardware and knowledge. Most surprisingly, time is not a significant issue. An explanation for this is that Dutch teachers realize that they already make many choices about how to spend their time and that GIS is a worthwhile expenditure of this scarce commodity. Most heartening to proponents of GIS education is the overwhelming number, 87%, asking for in-service training. This would appear to be the place to start in the Netherlands.

GIS in other parts of Europe: GISAS

On a larger scale, comparable to the US National Science Foundation efforts, the European Union has begun efforts to help select countries introduce GIS in secondary education. The Geographical Information Systems Applications for Schools (GISAS) project is a three-year education and research project funded by the MINERVA Action of the European Commission (Houtsonen *et al.*, 2004). Seven countries are participating in the 2003–2006 GISAS project: Belgium, France, Greece, Hungary, Italy, Latvia and Sweden. The aim of the project is to develop ways in which GIS can be applied in secondary schools and teacher training. The project uses *ArcView 8.3* software and focuses on water quality issues. The partner schools in the seven European countries create local GIS databases based on field observations and geographical, biological and chemical analyses. This information is mapped and analyzed with GIS and discussed by the students from the participating countries in a web-based learning environment.

Experiences from the GISAS project give additional information about the situation in other European countries. To gain a systematic understanding of conditions in each national context, two questionnaires have been completed by all participants. The purpose of the first questionnaire was to assess the situation in the participant's school and nation at the start of the project. The second questionnaire came half a year later and gave the external evaluators the opportunity to see whether the participants had made any progress toward project goals. The response to both questionnaires was 100%. The questionnaires were analyzed and summarized by two independent evaluators.

Table 1. Number of ICT classrooms and students per computer at the seven GISAS schools (Kankaanrinta, 2004)

Country	Number of ICT classrooms in each school	Number of students per computer
Belgium	1	28
France	3	12
Greece	1	50
Hungary	3	12
Italy	2	36
Latvia	1	11
Sweden	7	8

The first questionnaire indicated that almost none of the participants had experience in teaching about or with GIS and all requested more training in GIS and information about software, tools, geography content and how to use GIS in their own schools. Many participants faced practical problems such as a lack of time, money, training and tools. In the second questionnaire, although five out of seven countries reported that they were pleased with their progress, the lack of GIS skills, geographical knowledge and time were identified as the main obstacles to attaining immediate goals.

Seeing these barriers, the organizers of the GISAS project initiated GIS training and an individual support program via groupware. Important additional information comes from a study by Kankaanrinta (2004). This study shows the differences in ICT (information, communication and technology) facilities between the participating countries (see Table 1). Kankaanrinta also reports significant differences between countries in the quality of Internet connections and the amount of ICT training students receive.

Understanding why

In order to understand why GIS has failed to be adopted at a more rapid rate, it may be helpful to examine a general theoretical model of external and internal issues related to the implementation of educational reform. It takes considerable time and effort for any innovation to be implemented. This is particularly true in education. Stringfield (2002), studying nearly 20 multi-year, large-scale reform efforts over 15 years, concludes that reforms require more resources over longer periods of time than educators and policy-makers realize.

Four external factors may influence teachers' decisions to implement an educational innovation (Spady & Mitchell, 1979; Murray & Porter, 1996). We identify these as:

- authority;
- power;
- manageability;
- consistency.

In addition to these external factors, internal issues also influence teacher implementation of new practices. These issues are related to teachers' cognitive processes and the ways in which they come to understand the form and function of any innovation. First we discuss external factors that play a role in implementation, then explore internal processes which influence teacher decision making.

Authority

Educational decision makers, and teachers in particular, respond to authority, especially if there are significant consequences for not attending to official dictates. Authority can be established in several ways: by input from experts who develop a curriculum framework, through social norms that call for the inclusion of something that is familiar or through promotion by a charismatic leader touting a particular innovation. An example of such sponsorship is the almost universal change in the conceptualization of intelligence brought about by the work of Howard Gardner, a distinguished professor of education and cognition at Harvard University whose writings about the multiple aspects of intelligence have influenced a generation of educationists and psychologists (Gardner, 1985). An European example is provided by Leat (1998) and his colleagues who have successfully introduced 'thinking through geography' strategies in the UK, Norway and the Netherlands. Leat's wide and enthusiastic following shows how a passionate and clear thinker in geography education can move many teachers to reconsider their routines in geography teaching.

Power

Power, the second factor, is related to authority. Power plays a significant role when a new practice is enforced through a reward system or a form of sanction such as a high-stakes test or secondary school graduation requirement. Just as teachers, an essentially conservative group, respond to authority, they also respond to mandates, particularly if job security and pay are connected to implementation of an innovation. Teachers generally meet requirements, at least at a minimum level. For example, British geography students have traditionally done much more fieldwork than Dutch or US students at the same age group because fieldwork in the Netherlands and USA was optional whereas in the UK fieldwork was a mandated part of the syllabus. The integration of ICT into teaching has become more common only with its inclusion into curricular guidelines in the USA and Europe.

Manageability

The extent to which an innovation is explicit, clear and specific is important when teachers make decisions about what and how to teach. Innovations that are complex in form and function, hard to grasp and affect multiple aspects of the teaching–learning system are less likely to be implemented. For example, Madeline Hunter's lesson structure was widely adopted in the 1970s because it was prescriptive and manageable:

simple, linear, intuitive and generic (Hunter, 1982). The so-called lesson cycle method promoted by Hunter, a principal and education consultant, called for a rote, step-by-step process to teach any subject. In contrast, the High School Geography Project, also released in the same era, was not prescriptive in nature and not easily managed. It required concurrent changes in teacher understanding of geography, instructional strategies and classroom management practices for implementation. Thus, it was not widely adopted (Winston, 1986).

Consistency

Finally, the degree to which an innovation is aligned and consistent with other influences in the educational system is a factor affecting teacher implementation. Education is a complex, multi-elemental set of interlocking entities rife with inconsistent policies that teachers must reconcile and balance. For example, teachers are urged to be both student centered and knowledge centered, two opposing, often centrifugal, ideas. Similarly they may be asked to prepare students for high-stakes tests on content not in mandated textbooks and curriculum materials. If an innovation, in both its form and function, meets multiple educational goals, such as being rich in content, student centered and supported by existing curriculum materials, its adoption is nearly assured.

Internal issues

In addition to the external factors of authority, power, manageability and consistency, internal issues also influence teacher implementation of new practices. These issues are related to general processes of learning and motivation and are based on the assumption that research on how students learn can be applied to teachers (Bransford *et al.*, 1999). To a certain degree, educators need to be *persuaded* of the value of incorporating an educational reform like GIS into their classroom practice. Although the process of persuasion is complex and multidimensional, research indicates that it is also influenced by individual teachers' personal characteristics such as their prior knowledge, beliefs and interests related to the issue at hand (Murphy & Alexander, 2004). Hughes (2005) examined the nature of teachers' learning during technology professional development activities and the extent to which their subsequent technology-supported pedagogy was innovative. Her results confirmed the importance of internal issues in teacher adoption of technological innovation. She found that the power to develop innovative technology-supported pedagogy lay in the teacher's interpretation of the newly learned technology's value for supporting instruction and learning in the classroom; learning experiences grounded in content-based, technology examples were most effective toward this end. Furthermore, teachers with less professional knowledge and/or less intrinsic interest in identifying uses for technology required guided or collaborative, content-specific technology learning opportunities, while teachers with more professional knowledge were able to develop innovative technology-supported pedagogy by bringing their own learning goals to bear in professional development activities.

Teachers are the gatekeepers of educational reform and innovation. As Wallace (2004) indicates, teachers play a fundamental role in adoption and must be carefully guided and taught. This will mean attending to both the external institutional issues affecting educational decision making and the internal cognitive processes of individual teachers.

Lessons learned

In the first two sections of this article we reviewed the status of GIS implementation in the USA and various European countries and identified factors that appear to play a role in implementation. Next we presented a general theoretical model of external and internal factors that can help predict the likelihood that an educational innovation will be adopted. In this section we examine the status of GIS in relation to these factors.

To begin, it may be helpful to use our theoretical model to examine a widely adopted ICT, *PowerPoint*. *PowerPoint* is an example of a very successful educational technology tool. It is easy to learn (*manageability*), can be used on every standard computer with no particular technological demands (it has the *authority* of Microsoft supporting it) and helps students to meet key ICT skills required by most modern curricula (*power*). A second factor promoting *PowerPoint* is that its features and uses are consistent with accepted educational practice (*consistency*). The technology was designed for and is used to promote ICT skills; it offers teachers easy access to key skill development in many subject areas and does not demand teachers create new ways to teach. The process of persuading teachers to teach with and about *PowerPoint* was apparently not difficult given its wide use. *PowerPoint* complements teachers' existing internal perceptions of the teaching/learning process, fits well with their prior experiences, particularly in preparing lectures and organizing student presentations and is easily understood.

In contrast, GIS software has high technical demands, is a challenge to master, was not designed for a teaching/learning function and does not offer obvious opportunities for teaching/learning to many geography educators. We use each construct of our theoretical model to examine barriers to GIS implementation.

Authority, the first external factor in our model, is indicated by institutionalization in curricula, teachers' socialization processes, and encouragement by charismatic individuals. In evaluating the effects of authority on adoption of GIS we can identify individuals who have promoted this technology in different nations and contexts but no one with sufficient charisma or reach to move the technology into a greater number of classrooms. While GIS is slowly being written into curricular frameworks, it has been a challenge to make the case for its value given its high technical demands, difficulty to support in ordinary educational contexts, and expense.

Up to this point, no one has exerted any power, the enforcing tool of authority, to promote GIS implementation. In the countries considered in this article, educators who have adopted GIS are, for the most part, the early adopters, who tend to try new things before others because they are intrinsically motivated to excel and experiment;

they are not responding to any extrinsic reward system. Teacher evaluation and compensation systems in the United States and Europe have not yet recognized or placed GIS use in their schemes. With curricular changes and ensuing assessment adjustments, teachers may have additional power-related external incentives to include GIS in their teaching.

Consistency is measured by alignment and connection with other educational initiatives. Only when implementation of an educational reform (like GIS) is consistent with other educational initiatives will teachers find it advantageous to adopt it (Hughes, 2005). The case of the Netherlands is a good example. Curricular reform brought a new emphasis on student research, ICT use and consequent attention to local community studies. These initiatives sparked interest in GIS as teachers began to see its value in meeting multiple goals. In the USA, a federally funded initiative, The Partnership for 21st Century Skills, has selected geography as a model program because of the subject's ability to combine fundamental and valued learning and thinking skills such as problem solving and decision making with sophisticated technology tools like GIS (Partnership for 21st Century Skills, 2004). The Partnership is promoting GIS-rich geography because of its ability to achieve significant educational goals. This is highlighting GIS's alignment and consistency with broader goals. Such high-level support may be able to exert the authority and power teachers can leverage locally to obtain resources and time to incorporate GIS into their teaching.

Authority, power and consistency, while important, are the most distant external factors affecting implementation of GIS. Manageability is a more local, context-sensitive and immediate issue to teachers. It is clear from surveys and previous research that GIS has been slow to be adopted by educators because of its technical complexity. Manageability is also the issue most closely connected to internal cognitive processes in that a teacher's measure of whether an innovation is manageable relies on his or her perception of its value and degree of difficulty to implement. Internal factors influence teacher knowledge of, interest in and motivation to adopt GIS. Efforts to implement GIS have focused on teachers, relying upon them to make the changes necessary for adoption. However, as evident from the analysis of the status of the GIS vis-à-vis barriers to implementation, this strategy may be flawed. As Cohen (1995, p. 13) points out:

> Teachers are the problem that policy must solve in the sense that their modest knowledge and skills are one important reason why most instruction has been relatively didactic and unambitious. But teachers also are the agents on whom policy must rely to solve that problem, for unless they learn much more about the subjects they teach and devise new approaches to instruction, most students' learning will not change.

This statement highlights three of the most significant dimensions of manageability: teacher content knowledge, technical skills, and pedagogical style and skills.

It is clear from surveys and previous research that GIS has been slow to be taken up by educators because of its intellectual complexity. A teacher's internal conceptualization of the discipline and of teaching and learning geography influences his or her decision to use GIS. Educators with poor preparation in geography may simply not understand the fundamental concepts related to asking and answering significant spatialized questions. As Williams (2000) points out, careful thought is needed to devise the methods most effective for both teachers and students to introduce GIS into geography classrooms.

One value of viewing teacher implementation of educational innovation as an internal, cognitive process is that it helps GIS proponents to understand the role of teachers' content and pedagogical content knowledge with the ability to implement GIS. We can speculate that implementation of GIS will be more rapid in nations with specialized geography teachers like the Netherlands now that several technical and curricular issues have been resolved. However, we cannot assume that content knowledge alone is a single driving factor since as we see in the UK, GIS has also been slow to diffuse despite a well-trained and geographically literate teaching force.

Pedagogy and understandings of the role of the teacher in the learning process represent another challenge to educators. Traditional forms of schooling treat knowledge as a fixed commodity to be delivered from teachers to students. Many teachers and students are focused on facts and concepts, not on generalizations and relationships. Modern teaching, in comparison, strives for understanding, a process in which learners must play an active part. This epistemological shift requires teachers to develop a deep and broad understanding of their subject matter and to foster new pedagogical strategies. Teaching with and about GIS has little to do with traditional teaching. It requires striking a balance and moving teachers out of old ways of thinking while maintaining a strong connection to real practice (Stone Wiske *et al.*, 2001). GIS requires and capitalizes upon higher-order thinking skills. In order to foster such skills teachers and students may need to work in new ways such as through enquiry-based methods and problem-based learning (Audet & Ludwig, 2000).

We can summarize this examination of external and internal issues influencing GIS adoption by identifying two examples of GIS success that incorporate aspects of both, one from the USA and one from the Netherlands. The lack of supplemental materials and support from textbook providers, needed to guide less-than-knowledgeable teachers, are major impediments to integrating GIS into meaningful, easily implemented, classroom-ready and teacher-friendly curricula. Teachers need examples of simple and successful GIS lessons to be persuaded that teaching and learning with GIS is worthwhile. In the United States the textbook *Mapping Our World*, mentioned previously, has sold approximately 13,000 copies since its release in 2002. This single turnkey resource, linked to existing curriculum, organized into pedagogically familiar lessons and well supported by professional development workshops, has made GIS manageable and accessible for a wide audience of teachers. The publication comes with pre-formatted data and a one-year license for GIS software. The activities emphasize critical thinking and problem solving, consistent with national educational initiatives. The text also links and connects the materials to national educational standards, thus providing a degree of authority and power. *Mapping Our World* is a model of what may be needed to address the external factors (manageability, authority and power, and consistency) and internal issues (content knowledge and pedagogical familiarity) confronting teachers and delaying adoption of GIS. In the Netherlands, a comparable product is available from EduGIS (www.edugis.nl).

Teacher-friendly, secondary geography curriculum-aligned units have been developed by geographer educators and made available at this site. Dutch teachers have adopted these materials with great enthusiasm, building a base of support for GIS that is reaching a larger number of teachers. Based on this initial success, the government has granted a large sum of money to extend and implement EduGIS. This development bears observation to measure GIS implementation now that critical external and internal issues are being addressed.

In this article we have described the slow takeoff for GIS implementation in both the United States and some parts of Europe and suggested a wide range of reasons for this, using a framework of external factors and internal issues. So what are the lessons we have learned? Before beginning a list of recommendations, we should make our personal positions clear. Our attitude toward GIS could be characterized as skeptical enthusiasm. We have, like the early pioneers of GIS, been enthusiastic about its potential but unsure about its fit with the traditional geography curriculum as conceptualized by geography teachers. We have also come to realize that teacher preparation and teacher attitudes towards technology in general (and this technology in particular) need additional study and consideration. Boshuizen and Wopereis (2003) indicate that the fast-changing role and nature of ICT in education, combined with the low levels of penetration of technology into present educational practices, requires a multi-tiered approach to ensure the continued flow of emerging knowledge and practices to educational settings. The three-prong strategy they suggest includes the training of students within teacher training institutions, high-level implementation of ICT in schools as a cooperative effort of students, the schools themselves and the institutions which train teachers, and the formation of cooperating communities of practice to support and sustain growth and change. Currently teacher training in the USA, the Netherlands and elsewhere in Europe may not be producing teachers with the requisite skills to support GIS use and the kind of cooperative arrangement described by Boshuizen and Wopereis does not commonly exist. We should also state that we are surprised that GIS software and materials are not being designed to meet the needs of geography teachers interested in promoting student learning in addition to technical skills. We are mindful of the work of Wallace (2004) and Hughes (2005) which reinforces our observations that we as geography educators interested in GIS implementation have not lobbied hard enough for simpler software or provided the support average educators require to integrate technology to teach specific content.

With that, we can make three general recommendations. First, there is a need to continue to work to ensure that the external conditions exist to encourage and support GIS implementation. This means institutionalizing GIS into curricula, making sure that it is aligned with significant general learning goals like graphicacy, critical thinking and citizenship skills, and developing student assessment and teacher reward systems that accommodate GIS. It also means developing software and curriculum materials that are readily available, easy to maintain and, in a word, manageable. Second, there is a need to address the key internal issues related to GIS implementation. Obviously teacher training is critical here and we recommend a coordinated effort like that proposed by Boshuizen and Wopereis. From this second recommendation for coherency and coordination comes our third suggestion: use a community of learners approach to address both external and internal issues. The community of learners approach we propose may be scale sensitive, working best at a local and national level. However, with GISAS as a model, we may see a regional strategy being effective and there is much to be gained by developing an international community of learners as we hope we have illustrated in this article.

Note

1. The General Certificate in Secondary Education (GCSE) measures student achievement at the conclusion of required secondary education. The Advanced Level (A level) assessments follow after a further period of study, often as a pre-requisite to university entrance.

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