GIS in K-12 Education: Pedagogical Tool or Weapon of Mass Distraction?

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Introduction

The role of Geographic Information Systems (GIS) in K-12 education represents a terra incognita of sorts within geographic education. The improvements in the technological capacity of schools within the past decade coupled with the recognition of the power of educational technology for advancing student learning have led many educators to pursue the infusion of GIS in K-12 education. Although there are several examples in the literature of the successful implementation of GIS in schools (viz., Alibrandi, 2003; Donaldson, 2001; Keiper, 1999), there is a dearth of research in this field. Furthermore, there is a lack of consensus about the degree to which GIS is suitable for K-12 students. Given that so much is unknown about GIS in education, our recommendation to researchers in this field might well be to "study everything." In this paper, however, we will argue in favor of a more focused agenda for research. Specifically, we will recommend needed research in the areas of curriculum, instruction, and teacher education.

GIS and the K-12 Curriculum

The growing trend toward high-stakes testing requires that educators focus greater attention on the written curriculum. The maxim "what gets

tested is what gets taught" is increasingly true. Consequently, teachers' curricular decisions are constrained by the content of state assessments. This reality places GIS education in a precarious position. Does GIS serve important (read "tested") curricular goals? If it does not, then why should a teacher waste valuable time learning to use the tool and infusing it into his/her instruction? If GIS is seen as a curricular "add-on" or as a neat gizmo, then it is likely to be dismissed as fruitless. Much of the excitement in the GIS community about the use of GIS in K-12 education, though, is due precisely to the belief that GIS has the potential to accomplish a wide variety of important curricular goals. Yet, this vague sense of potential has not been well articulated or communicated to teachers or to those responsible for teacher preparation. For this reason, we see a need for curriculum inquiry research that addresses the fundamental questions of purpose, substance, and organization.

Purpose

What curricular ends does GIS have the potential to serve? This is a very complex question that requires significant attention if GIS is to take on a considerable role in K-12 education. As Kerski (2003, p. 135) noted, "The approach to GIS should not be, 'How can we get GIS into the curriculum?' but 'How can GIS help meet curricular goals?'" The work of Sui (1995) may provide a structure for exploring this question in the K-12 setting. Sui offered a pedagogical framework for linking GIS to the intellectual core of geography in higher education. One important distinction that Sui explored was teaching *about* GIS versus teaching *with* GIS. Teaching *about* GIS involves a curriculum that emphasizes concepts and theories. Students learn about the nature of geographic information and how such information can be represented and analyzed in a computer-mediated environment. This approach can be referred to as Geographic Information Science. On the other hand, teaching *with* GIS involves an emphasis on applying GIS to the investigation of topics within a variety of disciplines. Students learn to use GIS as a tool for investigating questions, but do not necessarily learn the underlying concepts behind GIS. As Sui (1995, p. 597) explained, both teaching about GIS and teaching with GIS are important curricular goals.

> For most geography students, GIS technology should not be an end in itself. Instead, it is a means to a higher end, to enrich geography's four grand traditions, to find new laws, and to have a more thorough understanding about human-environment interaction and various

> physical processes. If we fail to establish a tight bond between GIS and geography's intellectual core, GIS will remain a greatly improved means for unimproved ends. This demands that teaching about GIS should be well balanced with teaching with GIS.

Sui (1995) presents a compelling case for the curricular intersections between GIS and the discipline of geography at the post-secondary level. The task ahead for those concerned with GIS in K-12 education is to develop curricular models that explore the intersections of teaching about and with GIS and the K-12 curriculum in a variety of subject areas. What is the appropriate balance of teaching about GIS and teaching with GIS at the K-12 level? Some educators might argue that most of the concepts of GIScience are beyond the comprehension of K-12 students (particularly elementary level students). Others might suggest that teaching about GIS can occur at any age level with appropriate curricular organization and instructional strategies. The question of purpose is essential to this discourse. What do we want our K-12 students to gain from GIS? Do we want to develop their knowledge and skills related to the conceptual underpinnings of GIS? Do we want to develop their ability to use GIS software to explore geographic topics and real-world problems? Do we want both? Can we have both?

Substance

Questions of purpose naturally lead to questions of substance. Once we have determined our goals, or the ends we desire, we must begin to explore how we might accomplish those ends. In short, what should we teach? Again, this a complex question that requires considerable attention. If we determine that both teaching *about* GIS and teaching *with* GIS are valuable goals, then we must construct a curriculum that aims to develop both of these dimensions of GIS education. In the realm of teaching *about* GIS, we must determine which concepts and theories of GIScience should be taught in the curriculum of K-12 geography. In the realm of teaching *with* GIS, we need to consider how the tool can be used to accomplish a variety of curricular goals. Given the *what-gets-tested-is-what-gets-taught* environment of today's schools, GIS educators should devote attention to identifying the explicit connections between GIS and the standardized curriculum in geography and other relevant fields. For example, which concepts of GIScience could be taught in the context of the high school world regional geography course? In what ways could a middle school history teacher use GIS as a teaching tool to enhance

students' understanding of geographic influences on historical events? How might a math teacher use GIScience concepts to provide examples of real-world applications for mathematical operations? There exists great potential for GIS to serve as a significant component of the K-12 curriculum, but the content of teaching about GIS and teaching with GIS needs to be connected more explicitly to curricular goals and the written curriculum.

Organization

A final component of curriculum inquiry is determining the appropriate organization of the curriculum. The substance of the curriculum must be organized in some way for effective delivery to students at various levels. One of the most important dimensions of curriculum organization is sequencing. Which topics should be taught first? What do students need to know before they are introduced to a topic or procedure? What knowledge and which skills should be developed in which courses and at what grade levels? These questions arise both within courses and across courses. Within courses, teachers must determine an appropriate curriculum sequence to follow through the semester or school year. The written curriculum and the textbook often provide guidance in this decision-making process, but GIS enjoys no solid position in either of these curriculum guides. Furthermore, GIS enjoys no explicit position in the curriculum across grade levels. Thus, planning across grade levels must occur and the explicit links to the existing curriculum must be illuminated.

Kerski (2003) found that GIS implementation at the high school level was typically a result of the efforts of individual teachers working in isolation. Although the work of these individual teachers is potentially quite powerful, this form of GIS implementation is likely to be haphazard and fleeting. Curriculum models are needed that provide a structured sequence for GIS in K-12 education. This work should be based on the results of inquiry into the purpose and the substance of GIS in K-12 education. The resulting models will provide teachers with a coherent structure for teaching about GIS and teaching with GIS within various courses and across grade levels.

Instructional Issues

The relationship between curriculum and instruction is reciprocal rather than causal. One supports the other, rather than one leading to the other.

Nevertheless, we have chosen to present the research avenues in curriculum research prior to the research needed in the realm of instruction because we contend that future work in this field would be greatly enhanced if it is grounded in a coherent curriculum framework for incorporating GIS into the K-12 curriculum. Investigations into the value of particular instructional approaches will benefit from improved theory related to the purpose, the substance, and the organization of GIS curriculum. Similarly, research into instructional issues will inform the process of curriculum development. For example, research into cognitive development will greatly influence the decisions made regarding an appropriate sequence for GIS in the curriculum. In this section, we will explore the questions that might guide researchers as they investigate the instructional issues related to GIS in K-12 education. Specifically, we will consider the importance of research into cognitive development, teaching strategies, materials, and assessment.

Cognitive Development

GIS is often defined as consisting of four components: hardware, software, data, and a thinking operator. Educators are intrigued by the possibility that GIS might serve to advance the thinking of the operator. This potential raises numerous questions. Is GIS an effective means of developing higher-level thinking skills among students? At what age level is GIS appropriate given the cognitive development of the students? Does GIS require thinking that is too complex for some students? What forms of scaffolding are needed to support the use of GIS with students of varying cognitive ability levels? Fitzpatrick and Maguire (2001, p. 66) observed:

> Teachers can use GIS tools successfully in all levels of school. However, it is important that teachers carefully match the task or opportunity with the developmental level of the students. A mismatch between student, educational tool, learning objectives and instructional method can render even the most powerful tool ineffective.

Teachers need guidance from researchers in determining how best to match GIS tasks with the developmental level of students. For example, Bunch (2000) found that young adolescents struggle to acquire spatial information when presented with abundant concurrent layers of data. Researchers may provide guidance for teachers by investigating the implications of this finding. In what ways does GIS hinder rather than facilitate the acquisition of geographic knowledge? What strategies might be employed to avoid cognitive overload with students at various stages of development? This work will naturally draw from a strong line of research and theory regarding cognitive development, in general, and spatial cognition, in particular.

Teaching Strategies

Much of the existing evidence supporting the use of GIS in K-12 classrooms is anecdotal and based on the use of GIS as a tool for promoting constructivist pedagogy (Alibrandi, 2003). It is apparent that numerous teachers have uncovered successful strategies for employing GIS for a variety of purposes, but which of these strategies leads to greater student learning? The constructivist approach to instruction would seem to be a good match for GIS given the common use of the tool as a means for inquiring into geographical problems, but is there also a role for GIS in a behaviorist instructional setting? Is there some blend of constructivist and behaviorist-oriented pedagogy that will accomplish the desired ends of instruction about and with GIS? There exists promising research in problem-based learning and GIS (Baker & White, 2003; Bednarz, 2000), Web-based models for GIS learning, (Carver, Evans, & Kingston, 2004; Green, 2001a), and the use of multimedia classroom environments for GIS instruction (Deadman, Hall, Bain, Elliot, & Dudycha, 2000). Additional research is needed that extends and applies this work to other settings. Moreover, additional research is needed that compares the effectiveness of a variety of instructional models for GIS for accomplishing curricular goals.

Materials

Kerski (2003) found that fewer than 5% of all U.S. secondary schools own one of the three major GIS software packages (ArcView, IDRISI, or MapInfo) and that less than half of the teachers who own the software actually use it. The respondents to Kerski's survey noted barriers to the implementation of GIS in K-12 education such as lack of time for teachers to develop GIS-based lessons, little support for teacher training and implementation, and a perception that the software is complex. Two of these barriers (time and software complexity) point directly to a significant need for curriculum materials to support GIS education. There are a variety of questions in the area of

curriculum materials for GIS instruction that deserve research attention. For example, why do teachers who own GIS software packages not use them? Is one of the software packages better suited to K-12 education than others? Which media formats best support the widespread distribution and implementation of GIS-based lessons? Which lesson formats are teachers most likely to implement?

An additional barrier to GIS implementation is the availability of easily-accessible and ready-to-use data. Keiper (1999) found that there is tremendous value in the use of local data to support the investigation of authentic problems in students' home community. The acquisition and proper use of local data is quite challenging though (Green, 2001b). One alternative is to supply teachers with "canned" data that is not necessarily of local significance, but which can be used reliably to investigate geographic concepts. Researchers can assist teachers with this dilemma by investigating the value of local versus generic data in achieving desired outcomes through GIS instruction. Furthermore, researchers should investigate various means for disseminating GIS data and curriculum resources to teachers in user-friendly and cost-effective formats.

One additional avenue of research in the realm of materials for GIS instruction is the question of computer-based GIS versus manual GIS. Green (2001c) argues that manual overlay techniques can be used to effective ends and should be a component of a broadly conceived education about and with GIS. Green (2001c, p. 55) asserts:

> No matter how one chooses to use the IT [information technology] there is still a need to develop a progression in manual GIS throughout school education to provide for a sound knowledge of the principles of GIS as a vital prerequisite for computer-based GIS. This would avoid students merely 'button pushing,' which unfortunately is all too easy to do, leading to the acquisition of an end-product, e.g., a map, without knowing whether it is correct or what it means.

Assessment

It is important for educators to demonstrate the impact of instruction on students' knowledge and skills. As discussed earlier, standardized tests are a significant force within K-12 education today. Despite the enthusiasm among some educators over the use of GIS for instruction, it will be adopted much more readily if there is evidence that it has a positive effect on student achievement. Kerski (2003) encountered difficulties when attempting to measure student achievement gains in geographic knowledge and spatial reasoning and noted a need for improved instruments. Researchers should devote attention to constructing instruments that measure student acquisition of knowledge and skills in a variety of domains. Such instruments can be used as one tool for evaluating the effectiveness of teaching strategies, the use of various curriculum materials, and the developmental appropriateness of GIS based lessons.

Teacher Education

In 1999, Bednarz and Audet reported on the status of GIS in teacher preparation programs. They found that, "nationally, only a handful of schools expose pre-service teachers to GIS in an intentional and meaningful way" (Bednarz & Audet, 1999, p. 63). It is unlikely that the status of GIS in teacher education has improved significantly in recent years. Clearly, effective implementation of GIS at the K-12 level requires that teachers be knowledgeable about both the role of GIS in the curriculum and the instructional strategies that support the use of GIS. There are numerous avenues for research related to teacher education in GIS. For example, how is teacher knowledge of GIS best developed? Where within an already crowded pre-service teacher preparation curriculum should GIS receive attention? What forms of in-service teacher education are most effective in leading to implementation of GIS-based lessons? What forms of support do teachers need to effectively implement GIS instruction? Donaldson (2001) found that only 11% of his public school survey respondents had ever heard of GIS. Awareness of GIS is obviously needed, but given the complexity of GIS and the barriers to effective implementation, teacher education must go beyond simply exposing teachers to the existence of GIS. Such preparation should occur at both the pre-service and in-service levels.

Pre-Service Teacher Education

Gatrell (2004) presented one promising avenue for integrating GIS into pre-service teacher education through the International Society for Technology Education's National Education Technology Standards. Further research is needed into the role of GIS within the teacher education

curriculum. This line of work should involve questions of purpose, substance, and organization. For instance, what is the goal of GIS teacher education? Do teachers need to become expert users of GIS in order to teach about and with GIS? What foundation in geography do future teachers need in order to thoughtfully implement GIS in their instruction? How might GIS be infused more substantively into existing teacher education coursework such as elementary social studies methods and educational technology? Concomitant to this line of curriculum inquiry should be an examination of effective instructional strategies for GIS teacher education. For example, Doering (2005) has begun a promising line of inquiry into comparisons of instructional models for preparing teachers for GIS in K-12 education. Additional research should address issues such as, the awareness of GIS among university faculty in teacher education programs, the knowledge and skills of teacher educators related to GIS in education, the materials that are most effective for preparing teachers to teach about and with GIS, the teaching field experiences that support GIS teacher education, the effects of mentoring by skilled GIS teachers, and the effects of various curricular and instructional models in facilitating effective GIS implementation in K-12 settings.

In-Service Teacher Education

Bednarz and Audet (1999) noted that most teachers learn about GIS through in-service professional development opportunities rather than through pre-service coursework. Which models of in-service training result in effective implementation? Kerski (2003) observed that teachers are more likely to adopt and use GIS if a team of teachers from the same school are trained together. He also speculated that, given the constructivist orientation of much GIS instruction, perhaps "only those teachers who value an open-ended, exploratory approach to learning will adopt it" (Kerski, 2003, p. 131). These observations provide exceptionally fruitful lines of inquiry. Do teachers trained as a team implement GIS instruction more frequently and more effectively than teachers trained without a group of their school colleagues? If so, what models of team-oriented professional development are most effective? Does a teacher's pedagogical philosophy impact the likelihood that he or she will implement GIS? If so, can GIS pedagogy be designed such that it will be adopted by teachers of a variety of philosophical perspectives? Furthermore, given the rapid pace of technological innovation, what strategies might be employed for keeping teachers up-to-date with developments in GIS and its use in K-12 settings? When describing the GIS knowledge needed by students

and teachers, Fitzpatrick and Maguire (2001, p. 64) observed that, "More important than a thorough knowledge of the entire toolkit is a disposition for exploration and a capacity to think geographically – to search for relationships and pattern." The task ahead for teacher educators involves defining the knowledge, dispositions, and capacities that teachers need and then determining which approaches to teacher education most effectively result in those ends.

Conclusion

Any tool is most effective when it is being used for its intended purpose by a skilled handler. Any tool can also cause damage or become a weapon when it is used improperly. This is as true for hammers as it is for computers. The rapid pace of development of computer hardware, software, and networking within the past decade has both thrilled and bewildered many educators. The potential for computer technology to revolutionize K-12 education has generated great excitement among some educators. Others urge caution about the use of computer-based technology in schools. The future of GIS in K-12 education will depend greatly on whether or not good research on this innovation is forthcoming. Guided by such research, GIS has the potential to become a powerful pedagogical tool when employed for sound educational purposes by skilled users. Without research guidance, GIS could become a weapon of *mass distraction* in K-12 education.

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