Geographical Information Systems (GIS) in Education
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Introduction
The aim of this literature review is to provide educators with a basic understanding of Geographical Information Systems (GIS), their relevance to teaching and learning, and suggests possible strategies for implementing GIS technology in the classroom.

What are GIS?
Geographical Information Systems (GIS) can be described as general-purpose computer-based technologies for handling geographical data in digital form in order to capture, store, manipulate, analyse and display diverse sets of spatial or geo-referenced data (Burrough and McDonnell, 1998). In essence, GIS are spatial databases of digital maps which store information on various phenomena and their locations. With GIS, teachers and students can perform the following functions to answer various questions:

<table>
<thead>
<tr>
<th>Function</th>
<th>Kinds of questions asked</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Where is…?</td>
</tr>
<tr>
<td>Measurement</td>
<td>Length, distance, area, perimeter</td>
</tr>
<tr>
<td>Condition</td>
<td>Where is it? What state is it in?</td>
</tr>
<tr>
<td>Trend</td>
<td>What has changed?</td>
</tr>
<tr>
<td>Routing</td>
<td>Which is the best way?</td>
</tr>
<tr>
<td>Pattern</td>
<td>What is the pattern?</td>
</tr>
<tr>
<td>Modelling</td>
<td>What if?</td>
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</tbody>
</table>

Table 1. Basic Functions of a GIS. (Sources: Maguire and Dangermond, 1991 and Davis, 1996)

GIS have been used in a multitude of applications as ‘scientific tool[s] in natural resource management (forestry, agriculture, conservation), cave and karst research, environmental management, health and environmental health research, mining and petroleum research, hazards management and Earth science, among others’ (Walker, 2004, p. 3). Therefore, the skills and knowledge students acquire through GIS use in school may also enhance their future career prospects.

Increasingly, schools around the world are beginning to see the possibilities of using GIS for teaching and learning in not just Geography, but also in subjects like History, Biology and
Environmental Chemistry. Some students have also used GIS in their community service projects (eSchool News, 2006). According to Baker (2005, p.44), GIS is ‘emerging as an instructional technology for supporting contextually rich student learning’.

Scientific Visualisation and Inquiry-based Learning with GIS

One of the main strengths of using GIS in education is that they enable students to use maps and their databases to engage in ‘scientific visualisation’. Scientific visualisation refers to the process of interaction, manipulation and expression of information by the student.

As seen in Figure 1, visualisation can be used as a tool for scientific research. When students use map-based visualisation as learning tools, they gain a rich, immersive understanding of the concepts related to the data being explored, and also the skills in organising and communicating information in our data-rich environment.

Students who travel up and down the range of visualisation methods to constructively explore, discover and hypothesise on various scientific theories and concepts will no longer be passive recipients of information, but active discoverers and constructors of knowledge.

The scientific visualisation concept matches well with the inquiry-based learning approach recommended for the Science curriculum. This approach is also applicable to the teaching of human and physical geography, which are fundamentally regarded as social and environmental sciences respectively. In addition, the anchoring of geographical data in real-life phenomena provides many possibilities for implementing problem-based learning approaches in rich, authentic, educationally productive contexts.

Figure 1. Visualisation as a tool of scientific research. (Adapted from DiBiase, 1990 in MacEachren and Taylor 1994, p. 3).
Reasons for using GIS in Teaching and Learning

GIS have been identified as one of the 21st Century Tools for Communication, Information Processing and Research which will help to develop student abilities in investigating, evaluating, integrating, creating and analysing issues and information at various scales and locations (Partnership for 21st Century Skills, 2004). Therefore, GIS use in education will develop students’ information and media literacy, preparing them well for the digital age.

The unique nature of inquiry-based learning through GIS is the focus on spatial characteristics – location. The foundation of geographical thinking is to know “where something is, how its location influences its characteristics, and how its location influences relationships with other phenomena.” (Environmental Systems Research Institute - ESRI, 2003).

GIS enables the teacher to employ learner-centred approaches to delivering the curriculum, as compared to traditional didactic modes of delivery. By using authentic data for realistic outcomes, effective and engaged learning can be achieved.

Through GIS-enabled inquiry, students not only build knowledge related to the curriculum; they also develop critical thinking skills in managing, manipulating, querying, constructing and presenting information.

Research findings on the use of GIS in education have been encouraging. For example, Baker and White (2003, p. 243) have found that there were ‘significant improvement in attitudes toward technology, self-efficacy toward science, and modest, yet significant, improvements for geographic data analysis for [eighth-grade] students who used GIS’ in a ‘two week Project Based Learning unit’. In addition, Pang (2001, p. 5) found that Junior College students who had experienced dynamic and interactive visualisations through a GIS had ‘positive educational effect, especially in terms of creative and visual thinking’.

The cycle of Geographic Inquiry is a simple and useful 5-step framework for teachers to use when planning to implement GIS in the classroom:

1. Ask geographic questions
2. Acquire geographic resources
3. Explore geographic data
4. Analyse geographic information
5. Act upon geographic knowledge

Ask geographic questions
An interesting topic or place can be used as a starting point for generating good questions to set up the data exploration. For example, students may ask, ‘What will happen if the park in front of my school gets converted into a condominium housing estate?’ Good questions will guide teachers and students well in determining the geographic resources they would need.

Acquire geographic resources
The relevant geographic data for the proposed topic and area of study can usually be found as readily available packages or downloadable from the Internet. If the data is not available, the teacher could guide students in basic data collection through fieldwork.

Explore geographic data
Students can explore, manipulate and represent the collected data in the form of maps, tables and charts and achieve deeper levels of understanding of various concepts. Useful data could include temperature, layout of surrounding buildings, locations of trees and road networks.

Analyse geographic information
Students can then be guided to discern patterns and relationships in the phenomena being examined. For example, students may discover that there is a distinct temperature difference between places next to parks and those in more built-up areas. The GIS can efficiently solve queries and identify things, for example ‘Find all areas with average daily temperature more than 27°C’.

Act upon geographic knowledge
Having uncovered patterns, relationships and problems in real-life situations, students can then propose possible solutions and get involved. For
example, students may initiate a tree-planting Community Involvement Project in neighbourhood areas which may become warmer when the park is removed.

Two Possible Models of GIS use in Schools:

1. Data Exploration Approach – This is recommended for initial low-cost adoption of GIS for teaching and learning. Using free or low-cost GIS software and data, students can be tasked to explore the geographical information in a guided manner (e.g. using an inquiry-based or problem-based approach), and deduce patterns and relationships between various phenomena, and generate hypotheses on causes and effects. They will thus gain conceptual understanding and real-world knowledge from an authentic, evidence-based ‘ground-up’ approach. Teachers and students will also gain familiarity with the various GIS functionalities.

   For example, students may explore information on indicators of low standards of living (low income, illness, high crime rate) in different parts of a city. They could then hypothesise the interrelationships between the various phenomena and their locations, and discuss possible problems and solutions.

2. Fieldwork and Analysis Approach – This is recommended for teachers and students who have experienced the Data Exploration Approach and are already comfortable with using GIS. Questions and issues may arise from the Data Exploration approach, or from class discussions. Teachers may then guide students to embark on an investigative project involving fieldwork data collection and analysis.

   This approach may require the use of GIS with data creation, manipulation and analysis capabilities. Therefore, some additional cost may be incurred for software and hardware purchases.

   For example, students could find out the location and causes of pollution in and around the school environment. Using the GIS as a data collation and analysis platform, students could use data-loggers to collect data on air, water, land, heat and noise pollution from the
school neighbourhood and relate them to nearby land uses (e.g. roads, factories, shopping centres, etc.) and analyse the possible problems and solutions.

**GIS software and data**

Free GIS software with basic functions can be easily downloaded from the Internet and implemented in computer labs or classrooms. Another viable approach is to use Internet-based GIS which only require users to have web browsers like Internet Explorer or Firefox. Google Earth software combines satellite images with geographical information to provide users with a data-rich, intuitive and interactive platform in order to explore various phenomena at different locations on Earth.

GIS software with advanced editing and analysis capabilities for various operating systems and platforms can be purchased from companies like Environmental Systems Research Institute (ESRI), AsiaGIS and Intergraph. GRASS GIS is a free and Open Source GIS with high-level functionalities.

Large amounts of GIS data are available for free or low-cost download over the Internet. In addition, GIS data is usually conveniently packaged with each commercial software purchase.

Therefore, current developments in GIS have led to an ideal educational environment for teachers to facilitate the development of students’ knowledge and skills in different subject areas through the use of GIS technology.
Questions that should be asked before using GIS for Teaching and Learning:

The following questions can be used by teachers to guide their planning of the use of GIS for teaching and learning:

(a) How can students’ learning be scaffolded through GIS use?

(b) How does the usefulness of GIS technology help teachers to facilitate effective and engaging learning experiences for students in various subjects and topics?

(c) Has sufficient time been factored-in for teachers and students to learn the basic skills of using GIS software?

(d) Where can the required data be obtained? If students are involved in searching for and creating data, what is the value-add of them doing so?

(e) Have there been adequate preparations in terms of time, scaffolding for students, and equipment for students to collect data?

Conclusion

GIS technology provides many opportunities for teachers to implement learner-centred approaches for various subjects in an authentic, engaging, integrated and holistic manner. Together with the increasing availability of affordable GIS software and data, the time is ripe to bring GIS-enabled teaching and learning approaches into the classroom.
Useful weblinks:

ArcExplorer - GIS Data Viewer
http://www.esri.com/arcexplorer

ArcLessons: Your resource for GIS Educational Exercises:
http://gis2.esri.com/industries/education/arclessons/arclessons.cfm

ESRI Schools and Libraries Program
http://www.esri.com/k-12

GIS and Geographic Inquiry
http://www.eschoolnews.com/resources/reports/gis/index.cfm

GRASS (Geographic Resources Analysis Support System) GIS
http://grass.itc.it/

Google Earth
http://earth.google.com

Google Maps
http://maps.google.com/

KanGIS Community of K-12 Educators
http://kangis.org/learning/ed_docs/gisNed1.cfm

Why use GIS? (Reasons and Resources for GIS)
http://serc.carleton.edu/introgeo/gis/why_use_GIS.html
References


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