Full Length Research Paper

Advancing the frontiers of spatial thinking: Using GIS across Curriculum in teaching and teaching

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The onset of Information and Communication Technology has introduced diverse ways of learning and teaching. Even as geo-technology is at the leading edge of geography’s increased awareness in Kenya today, such developments have not translated into significant achievements in education. Hitherto to now, the number of student enrollments into geography are still low and even those taking the subject are doing so out of curiosity and convenience. The negligence of geography in many schools within Kenya has continued to work against the discipline’s strong presence in the country’s colleges and universities. Since some of the most innovative work today in geography is taking place at the intersection between Geographic Information Systems (GIS), Geo-Information Science and Geography as observed by Kwan 2004, there is a need to use these tools to enhance the teaching of geography and improve the quality of the geography being learnt. GIS comes in as a powerful technology with opportunity to promote issues based learning, student centered and inquiry oriented education which are seen as crucial pedagogical approaches to the learning of geography and related disciplines today. The irony is that despite GIS’s potential to enhance spatial thinking, it remains out of reach for most students in many schools. This paper sought to explore the opportunities presented by the current geo-spatial tools in enhancing spatial thinking and multi-disciplinary understanding of key concepts in disciplines like geography, Agriculture and Biology. The approach adopted here is GIS Problem Based Learning where selected topics from the Kenyan secondary schools curriculum Text books have been used to demonstrate how to teach spatial concepts using GIS. A brief comment is made on the foreseeable challenges of using GIS in teaching and learning and how to address them.

Key words: Curriculum, GIS, Spatial Thinking, Geography, Student enrollments, Problem Based Learning.

INTRODUCTION

Spatial literacy is slowly but surely developing foothold in Kenya with the current trend driven by the increasing wave of geographic awareness originating from the unprecedented natural and technological disasters witnessed in the country of late. Such include: floods, drought, conflicts in the nearby states, urban fires, the changing political landscape, terrorism and climate change among others. Generally geospatial technologies are receiving mainstream attention across the world with Web-based maps and virtual globes like Google Earth increasing in popularity (Gewin, 2004). Luckily enough, this interest is contributing to the growth of geography at all levels of academe (Pandit, 2006; Murphy,2007). Geography has played a major role in advancing spatial literacy in Kenya. This is evidenced by the increasing number of secondary schools and universities mounting geography subjects into their curricula which was lacking there before. Spatial thinking now is becoming an important and marketable skill for students in the competitive Job markets especially in the fields of commerce, Utility, Health, Administration, learning, Non-Governmental Organisations and Research Community. Spatial Thinking is the ability to visualize and interpret location, distance, direction, relationships, movement and changes through space. According to the National Research Council 2006, Geographic Information Systems

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(GIS) has the potential to enhance spatial thinking. As a tool, GIS can be used for display, inquiry and analysis in problem based learning (Drennon, 2005). From an educational perspective, GIS is envisaged as an invaluable resource for use in extending a learner’s understanding of geography because it supports the visual illustration, and manipulation of central concepts of the discipline. Geographic Information Systems and related Geo Spatial Technologies are now a fast-growing area in Kenya today. The technology is currently used by a number of key industry players like; water companies, local government departments, government institutions, consulting firms and even universities. Despite the increasing growth of GIS Use in Kenya, it is yet to find its way into the school syllabus. The curriculum for GIS is lacking and it’s only a few institutions which offer a GIS degree or have a spatial component in their Courses (Gachari, M.K, 2001). Most institutions are now developing GIS curricula to suit their own programs while others use those developed and used elsewhere (Zietsman, 2002). Geographers should therefore step in and help in organizing the subject, show what principles to bring out and assist geography teachers in deciding between the important and the unimportant aspects of the subject. For example, they should help in the planning and execution of fieldwork, offer guidance on the study of maps and contribute towards making geography study in schools value full (Richard Elwood, 1906). Since GIS creates openings to cultivate a spatial perspective within diverse curricula and encourage thinking about geography in the wider sphere (Diana Stuart,2009), this paper seek to identify topics which are geographically resourceful from selected subjects in the Kenyan secondary schools curricular and demonstrate how GIS can be used to develop Spatial Thinking Skills to students.

**PEDAGOGIC STRATEGY AND APPROACHES**

The concept of space is not only important within geography but also in Physical, natural and social sciences. The irony however, is that the current approaches do not foster a spatially infused learning where geography and GIS are integrated together to help visualize knowledge, solve problems and understand relationships within a spatial context. More often, to appreciate the pedagogic objectives of critical thinking and problem-based learning, spatial thinking is crucial and it is now than before being promoted through Geographic Information Systems and other Geospatial Techniques.

According to Learning to Think Spatially, three types of spatial thinking exists: thinking in space, thinking about space and thinking with space. Thinking in space requires thinking in a real-world context to help perform actions like walking, driving. Thinking about space focus on a scientific understanding of the nature, structure and function of phenomena; for example how solar energy reaches the earth’s surface. Thinking with space deals with the conversion of some data relationship between objects into locations and arrangements of the objects in a space. Thinking in space for instance promotes thinking about space, whereas the use of space as a cognitive strategy adds power and aids in thinking in and about space (Bednarz, S., 2005).

Knowing where things are located, how location influence characteristics of features as well as relationship with other phenomena form the basis of geographic inquiry with space as the central theme. This method of inquiry advocates; asking geographic questions, Acquiring geographic resources, Exploring geographic data and Analysis of geographic Information. Since geographic inquiry can be used to investigate any subject at any level, this method is adopted to teach students to think with space using GIS as a tool. The use of GIS in the classroom calls for new approaches to curriculum–building, teaching and the assessment of the student performance (Lee Y., Geok C. Tan, et al 2008).

**Curriculum**

Lessons in many subjects today can be rendered using GIS because they have a spatial component in them. These include; climate, weather events, water resources, ecology, conservation, agriculture, pollution and geography themes such as field work, vegetation, energy, population, tourism and wildlife among others. For this paper, the Environmental Education Curriculum for Secondary schools in Kenya will be used because of its multidisciplinary content. In this case, selected topics from the curricular will be implemented with GIS. The GIS supported-curricular developed for this study involves a computer for demonstrating the software and GIS-based inquiry methodology with emphasizes on problem based learning. The model adopted is the structured Problem Based Learning GIS approach (Sara.W, 2000) where the teacher assumes a prominent class room role with students being less autonomous. This approach involves the following:

- Selection of a Topic.
- Development of a Case Scenario.
- Decision on the products and possible Outcomes.
- Creation of a suitable work plan.
- Analysis and presentation of the Results/Findings.

**Instruction**

Various teaching methods exists which include lecturing, field work and lab practicals. Instructional approaches applying questions which lead students from familiar
examples to new understandings are useful for teaching thinking skills as well as content (Rosenshine1983). For a GIS based lesson, it is important to expose students to GIS skills as well the Subject-matter content. Closed lesson instruction which give students all the instructions and data to solve a Specific problem is chosen because it has an easy to use format compared to an open lesson where students must gather data and solve problems on their own or in groups based on the general guidelines. The closed lesson instructional approach found in Mapping Our World (Malone, Palmer, and Voigt 2002) is adopted for this case. This includes:

- Lesson Introduction
- Lesson Materials and Time
- National Geography standards covered in the lesson.
- Lesson Objectives
- GIS Skills Useful for the lesson
- Student Activity (Hands on using GIS Software)
- Conclusion

Assessment

Several evaluation tools can be used to assess the student’s performance. Such include; traditional assessment methods like multiple-choice, true/false, short-answer, essay tests and performance-based evaluation criteria with product creation, process-oriented evaluation and portfolios have been used widely in GIS training (Thomas. R. et al, 2009). For this study, the focus is on the student’s products and performance incorporating a variety of assessment tools. A scoring guide measuring all outcomes such as content knowledge, results communication and mastery of GIS Skills will be used. The scoring rubrics showing the student’s expectations is good because it provides specific feedback to students showing where there is a need for additional assistance, practice or improvement.

HOW TO TEACH SPATIAL PERSPECTIVES WITH GIS: Example with selected Subjects from Kenya’s Secondary School Syllabus

<table>
<thead>
<tr>
<th>Geography Standard</th>
<th>Objectives of the Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective</td>
<td>Students understands how to use maps and other graphic representations to depict geographic problems</td>
</tr>
<tr>
<td>How physical systems affect human systems</td>
<td>Students understands how changes in the physical environment can diminish its capacity to support human activity</td>
</tr>
</tbody>
</table>

GIS Skills to Learn

- Loading data into GIS
- Opening attributes table
- Feature Selection
- Labeling of features

Report generation and Graphs
- Creating Maps in GIS

Student Activity

- Observe and Analyse the Rainfall and temperature
patterns using GIS
- Analyse the impacts of Climate on Agriculture and population distribution
- Explore the relationship between Rainfall, Temperature and Physical features.

**Students Resources**

**GIS Investigation Sheet** lay out integrating the Geographic Inquiry methodology

1. Start Arc GIS
2. Load the Data
3. Open the Attribute table
4. Observe the rainfall and Temperature Patterns
5. Label the map
6. Test the Hypothesis
7. Investigate the impacts of weather elements on human activities Create a map and report

**Answer Sheet lay out (Sample)**

NAME_________________ DATE____________________

1. Write THREE observations made about Temperature Patterns displayed on the Map
   _____________________________
   _____________________________
   _____________________________

2. Use the Identity tool to find information on cities

<table>
<thead>
<tr>
<th>Name</th>
<th>Temperature</th>
<th>Altitude</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Based on the Information displayed in the Attribute table and Map, Formulate a hypothesis about the relationship between altitude and Temperature _____________________________

4. Complete the table below and say whether the observations made confirm or dispute the hypothesis, Explain _____________________________

<table>
<thead>
<tr>
<th>Town</th>
<th>Latitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandera</td>
<td></td>
</tr>
<tr>
<td>Nanyuki</td>
<td></td>
</tr>
<tr>
<td>Athi river</td>
<td></td>
</tr>
</tbody>
</table>

**Assessment sheet (Sample)**

*Part1.*

Use the Arc GIS project and Answer Sheet, tick the probable factors influencing the given city’s temperature pattern.

<table>
<thead>
<tr>
<th>Town Name</th>
<th>Factors that Influence Temperature Patterns</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Location</td>
</tr>
<tr>
<td></td>
<td>Location</td>
</tr>
<tr>
<td></td>
<td>Location</td>
</tr>
</tbody>
</table>

*Part2.*

Using your GIS Investigation and other resources like Text books, write an essay that on how location influences temperature. Use Examples of cities and data to support your argument. Finally create a map in Arc GIS to illustrate your conclusions.

**Suggested Activities**

- Visit a Water treatment plant or a Water company in the nearest town.
- Use GIS to identify areas likely to experience water shortage
- Formulate hypothesis about the relationship between Water Supply and Conflicts.

**Resources:**

- Data sets (Maps, Attributes data)
- GIS Knowledge
- Students Hand outs (Questions, Practical Manuals and guidelines).

**Anticipated challenges and implementation milestones**

According to Verbeek2000, using an instrument in learning process affects not only how we learn but also potentially what we learn. This is the case with GIS when used for the first time in classroom because it calls for restructuring of the existing curricular in order to accommodate diverse teaching methods like Problem-based learning (Drennon, 2005), Self–Learning Modules (Zerger et al., 2002) and Use of Multi-media in classroom (Dead man et al., 2000).

The most likely challenge in this endeavour is how to bring out the spatial perspectives in other subjects than Geography which have traditionally used descriptive essay methods. To identify topics and how to put a spatial component in them may lead to a complete change of the subject contents. Basically the constraints may be classified as technical and pedagogical. Technical Constraints include; complexity of the GIS software where constant retraining is a need for GIS Skills enhancement because the GIS in the market keep on improving in analytical capabilities. Other challenges
like the lack of useful data, hardware problems, lack of GIS training, incompetence in the use of GIS software and the high cost of hardware and software are foreseeable impediments to the successful GIS implementation. Pedagogical constraints are not limited to the availability of GIS instructional resources, lack of geographical training and skills, but include rigid curriculum characterized by short lesson periods and limited field work. These limitations continue to pose great challenges when it comes to the adoption and sustained use of technologies in education particularly GIS which are complex and technical in nature.
<table>
<thead>
<tr>
<th>Town Name</th>
<th>Av_ Max Temp °C</th>
<th>Av_ Min Temp °C</th>
<th>Average Temp °C</th>
<th>Average Rainfall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marsabit</td>
<td>30.2</td>
<td>10.1</td>
<td>20.1</td>
<td>859</td>
</tr>
<tr>
<td>Wajir</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mandera</td>
<td>44</td>
<td>14.6</td>
<td>29.3</td>
<td>247</td>
</tr>
<tr>
<td>Kisumu</td>
<td>35</td>
<td>11.7</td>
<td>23.3</td>
<td>1352</td>
</tr>
<tr>
<td>Kakamega</td>
<td>30.8</td>
<td>10.3</td>
<td>20.5</td>
<td>1952</td>
</tr>
<tr>
<td>Nanyuki</td>
<td>40.9</td>
<td>13.6</td>
<td>27.3</td>
<td>956</td>
</tr>
<tr>
<td>Isiolo</td>
<td>30.1</td>
<td>16.7</td>
<td>23.4</td>
<td>613</td>
</tr>
<tr>
<td>Embu</td>
<td>28.8</td>
<td>9.6</td>
<td>19.2</td>
<td>1206</td>
</tr>
<tr>
<td>Nairobi City</td>
<td>24.8</td>
<td>12.8</td>
<td>18.8</td>
<td>926</td>
</tr>
<tr>
<td>Athi River</td>
<td>28.5</td>
<td>12.8</td>
<td>19.3</td>
<td>744</td>
</tr>
<tr>
<td>Mombasa</td>
<td>39.3</td>
<td>13.1</td>
<td>26.2</td>
<td>1053</td>
</tr>
</tbody>
</table>

- Water pollution
- Conflicts on water supply and Security
- Water resource management

The National Geographic Standards

<table>
<thead>
<tr>
<th>Objective of the Standard</th>
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</thead>
<tbody>
<tr>
<td>How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective</td>
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<tr>
<td>Students understand how to use maps and other graphic representations to depict geographic problems</td>
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</table>

<table>
<thead>
<tr>
<th>Objective of the Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>How to apply geography to interpret the present and plan for the future.</td>
</tr>
<tr>
<td>Student understands contemporary issues in the context of spatial and environmental perspectives</td>
</tr>
</tbody>
</table>

Figure 2: Map of the rivers and Drainage systems in Central and East Africa
How to sustaining geospatial technologies in Kenyan schools

The presence of GIS and related geo-technologies in Kenyan education sector is minimal if any compared to other fields like in business, communication, security, utility and even Transport. There is a need for proactive efforts between the academia and the GIS industry players to create more awareness especially at the pre collegiate levels (Primary and Secondary schools) through events such as Geography Awareness week and GIS days. At the university level, GIS based Students research projects should be encouraged to strengthen the presence of Geo-Spatial Technologies in research and development. There is a need for locally derived data to help in the understanding of our immediate environment and for use in teaching of geography and related disciplines in secondary schools. The development of GIS based instruction materials, curriculum, Assessments tools and other teaching support systems should be considered before rolling out GIS in Schools if it is to remain sustainable in the long run.

CONCLUSION

GIS can support Spatial learning if the inquiry method of teaching is adopted. This is because it is capable of integrating diverse datasets from many and different disciplines if the emphasizes is on the “Space”. This call for Field based approaches which encourage problem identification, analysis and solutions within a spatial perspective and centered on GIS. With the onset of ICT in Kenya, GIS based lessons are a necessity to tap in the increasing everywhere potentials of the Geospatial Technologies and bring them into classrooms where such knowledge will impart both the present and future schooling generations. The possible implications of using a GIS-supported curricular is that it will cut across several disciplines like Biology, Agriculture, Geography, Mathematics, Physics and Earth Science. This in turn will enhance a mechanism by which students may reason both in and with geography leading to spatial thinking skills (Gregg et al 1997). The Enthusiasm brought about by GIS supported geography lessons will see more students like and choose geography as a subject of value to them slowly undoing the current situation where more students are flocking to history and Religion classes.

REFERENCE

Diana Stuart Sinton (2009): Roles for GIS within Higher Education. J. Geo. in Higher Educ. 33(S1): S7-S16


