Enable Spatial Thinking Using GIS and Satellite Remote Sensing – A Teacher-Friendly Approach

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Abstract

The New Senior Secondary (NSS) curriculum has been implemented in Hong Kong since September, 2009. One major objective of this initiative is to help students acquire critical thinking, information technology and life-long learning skills through the Independent Enquiry Learning (IEL) approach. Geographical Information System (GIS) and Satellite Remote Sensing (RS) can be very effective tools for multiple subjects in the NSS curriculum, particularly in Geography and Liberal Studies. However, there exists a huge technical barrier for teachers to apply the technologies in the ordinary classrooms. Hence, this project, funded by the Quality Education Fund of the Hong Kong SAR Government, aims to support the teachers of Hong Kong using GIS and satellite remote sensing in their classrooms. The implementation approach is designed totally from a practitioner's perspective; hence, the fundamental brief of this project is to develop useful resources for teachers and the products shall be: 1.) Teachers and Students - Friendly; 2.) Encourage students to practice critical thinking and spatial thinking skills; 3.) Encourage students to apply knowledge / experience acquired through the learning activities to the other field of interests; 4.) Lowering the barrier of transforming teachers' / students' creativity to practical GIS / Remote Sensing projects and learning activities.

Products of this project include a comprehensive resources pool of GIS Data and Remote Sensing Images; a teacher-friendly GIS and satellite image processing software; teachers' training workshops and mostly important, school-based supports. This paper will highlight the first batch of achievements and products, evaluations, successful cases of classroom implementation as well as the feedback from the frontline teachers.

Keywords: Satellite Remote Sensing; GIS; Spatial Thinking; Geography Education;

1. Introduction: Education reform in Hong Kong and spatial thinking skills

The New Senior Secondary (NSS) curriculum has been implemented in Hong Kong since 2009. One major objective of this initiative is to realize the vision of “learning to learn” in which students are helped...
to acquire critical thinking, information technology and life-long learning skills [1, 2]. Incorporation of an Independent Enquiry Learning (IEL) approach is an essential initiative to achieve the stated objectives.

To enhance teachers’ readiness for this initiative, many researchers and educators conduct innovative projects and works. Those works provide huge support to frontline teachers guiding their students in IEL skills. This project specifically focuses on developing a practical approach using GIS and Satellite Remote Sensing (RS) in IEL. We investigated how the GIS and RS can enhance students’ capabilities in Spatial Thinking Skills [3] and connecting knowledge from different subjects and eventually provide powerful support to frontline teachers and students throughout the implementation of IEL.

Spatial Thinking Skills introduce learning with maps and spatial information, allow students identifying spatial patterns and relationships among data related to different topics of studies (e.g. public health, population, transportation, cultural characteristics etc.) and encourage students to explain and to connect cross-disciplinary knowledge through the identified spatial patterns / relationships [3]. Geographical Information System (GIS) and Satellite Remote Sensing (RS) could be essential technologies supporting Spatial Thinking in secondary classroom. As Downs (2004) suggested [4], “GIS can reflect the best of geography. It does much to support spatial thinking and to enhance geographic literacy.” Meanwhile, Satellite Remote Sensing is a unique technology that provides timely, boundary-free data to the classroom in response to major ad hoc events and natural disasters anywhere in the world. It provides a fruitful real time data source for spatial thinkers studying the present-day phenomena in the real world. Thus, many researches applied Satellite Remote Sensing in geography and science education [5, 6, 7].

Despite of the advantages of the new technologies, some researches pointed out the existence of many huge obstacles for successful implementation of GIS and RS in the classrooms. As the NRC report [8] pointed out, the new technologies were originally developed for intensively trained professional peoples. In one sense, they are too powerful and too difficult to learn for most K-12 users. Although many attempts had been made, there is still a huge technical barrier to implement GIS and RS in ordinary secondary schools. Hence, Commercial GIS software is not the “total solution”, but can be an essential part of it if the following issues are addressed: 1.) Overcoming the visualizing limits in 3D and time; 2.) Providing graded version of GIS and 3.) Making the software “teacher friendly” [8].

Moreover, there are also arguments on how GIS & RS can be implemented such that the technologies can actually enhance and support geography teaching / learning rather than becoming another burden to the over-loaded frontline teachers. Latest research even questioned the actual benefit of following GIS instruction to the improvement of spatial thinking skills [9]. Researcher compared the efficiency of hands-on mapping activities with simply following GIS-based instruction and found no significant different in improving spatial thinking abilities. The research evaluated the true benefits of GIS in secondary education and concluded that GIS can bring positive effect on students’ spatial thinking abilities only if two critical factors are met [9]: Firstly, teaching for understanding: Understand the geographic phenomena and / or sciences behind the complex GIS operations. Secondly, ability to extend what is learned in one context to other contexts: Apply the skills to another scope of study.

Similar to Bednarz’s observations [9], researchers raised the question of whether the secondary teachers should “teach with GIS” or “teach about GIS” [10]. The former focuses on software-specific procedure steps while the later highlights learning science, geography concepts, spatial problem solving. This approach moves GIS education from technical training to stimulation education.

Shortening the gap between the professional GIS software and the actual needs of secondary teachers and students, current approaches focuses on simplifying users interfaces of powerful GIS software and re-organizing activities into science and geography contexts [10]. These approaches lowered the technical barriers and, following the instructions and steps with the provided data sets in the teaching packages, teachers can actually teach science and geography with GIS. However, those packages provide limited topics and teaching modules only. Mostly important, the materials are developed based on the top-down approach in which experts outside the schools develop the materials, specific needs of individual school
Table 1. Key spatial thinking skills [3]

<table>
<thead>
<tr>
<th>Spatial Thinking Skills</th>
<th>Key question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Where is the place?</td>
</tr>
<tr>
<td>Condition</td>
<td>What is at the place?</td>
</tr>
<tr>
<td>Connection</td>
<td>How is the place linked to other places?</td>
</tr>
<tr>
<td>Comparison</td>
<td>How are places similar or different?</td>
</tr>
<tr>
<td>Aura (Influence)</td>
<td>How far from a feature is its influence significant?</td>
</tr>
<tr>
<td>Region</td>
<td>What nearby places are similar to this one?</td>
</tr>
<tr>
<td>Analog</td>
<td>What distant places are similar to this one?</td>
</tr>
<tr>
<td>Transition</td>
<td>What happens in the border zone between places?</td>
</tr>
<tr>
<td>Pattern</td>
<td>Are there biases, clusters, strings, doughnuts, waves, other patterns?</td>
</tr>
<tr>
<td>Correlation</td>
<td>Are the spatial pattern similar?</td>
</tr>
<tr>
<td>Residual</td>
<td>What are the exceptions to the observed “rule”?</td>
</tr>
<tr>
<td>Diffusion</td>
<td>How do things spread through space?</td>
</tr>
<tr>
<td>Space Model</td>
<td>Are places linked by a process?</td>
</tr>
</tbody>
</table>

and particular interests of teacher are generally neglected. Without the teachers’ involvements in the design process, this “top-down” approach can hardly secure teachers’ commitment and may generate teachers’ resistance [11]. The root cause of the “top-down” approach is two-fold, spatial analysis function of commercial GIS package is “too complicated and too powerful” for teachers and specific GIS data for particular topics can hardly be produced by frontline teachers.

This project re-thinks the positions of GIS and RS in secondary school education and develops a bottom-up approach in which frontline teachers can take the initiatives in GIS and RS instruction in the classrooms. We developed a series of supporting tools tailor-made for the frontline schoolteachers to support the new approach. Our development bases on the following principles:

In secondary schools teaching, we suggested that the emphasis of teaching should be shifted from “performing advanced spatial analysis” to “the freedom of integrating facts of any perspectives spatially” and “enabling spatial thinking such that students can explore spatial patterns and relationships among those perspectives.” Hence, GIS should mainly act as a platform integrating knowledge and facts of various subjects, provide simple tools to practice spatial thinking skills and study the inter-relations among the collected facts, combine the observations with taught knowledge and explain / draw conclusion for the study accordingly. The essential roles of GIS include data integration, identification spatial patterns and relations among co-located facts among various perspectives, data visualization (e.g. providing three-dimensional visualization capability etc.).

Following the basic design principles, we attempted to develop a “button-up” approach with which teachers can manipulate the materials design and development by simply gathering and integrating topic specific GIS and RS Images into a single analysis platform (i.e. GIS). Moreover, teachers can freely
introduce any spatial data and explore the spatial relations among the data with their professional knowledge and creativity in the subject areas. As such, we defined the following objectives for this project: Firstly, the deliverables (e.g. software, web-based resources, teaching materials etc.) shall be teachers / students- friendly. Secondly, the deliverables shall encourage students to practice spatial thinking skills, software-specified instructions shall be kept as minimal. Thirdly, the deliverables shall lower the technical barrier of transforming students’ creativities as well as teachers’ professional knowledge into GIS / Remote Sensing study projects and learning activities. Lastly, the deliverables shall encourage teachers / students to apply knowledge / experience acquired through the learning activities to other contexts of various subjects.

Based on our design principle, our primary objective is developing an ease-to-use platform of GIS & RS for teachers and students integrating map-based facts and information. The developed platform and the interactive learning experience shall play an essential role for the students conducting Independent Enquiry Study (IES). IES is an integral component in the curriculum of Liberal Studies and is designed to provide a student-directed learning experience and requires student leading an investigative study of a self-chosen topic [1]. Through the IES learning process, students are encouraged exploring spatial relations and patterns among data and drawing sensible explanations towards the observations.

2. Applying Spatial Thinking in Independent Enquiry Study (IES)

2.1. Spatial Data Integration

The first task applying spatial thinking is the integration of relevant spatial information. Apart from free LandsAT satellite images obtained from NASA and free resources obtained from other satellite ground receiving stations [12]. Many resources are available from the Internet. However, those resources are usually digital images (e.g. JPEG, TIFF images) without geo-references. There exists difficulties in integrating (i.e. overlaying) those digital images. The Project Team aims to develop simple methods and computer software just that all those Internet resources can be integrated into a common analysis platform. With the platform, students can draw a sensible conclusion considering various facts and materials. The entire spatial data collection process should be easy as searching other textual information form the Internet. Hence, the Project Team developed software tools for the project teachers and students: KML Utility. The software aligns various spatial information with a common co-ordinates referencing systems (i.e. geo-referencing).

The KML Utility software support common image formats such as TIFF, JPEG, GIF, BMP etc. Assuming a student collected various spatial information covering the studying area including scanned map from textbook, satellite images, aerial photos and digital census maps from the Internet etc. The student can import those images to the software. Meanwhile, the students can select well-defined features such as concerns of coastline, grid lines, road junctions, buildings etc. as ground control points and acquire the geographic co-ordinates (i.e. Latitude and Longitude) easily from other resources such as Google Earth™ and Microsoft Virtual Earth™ etc. The software allows students to identify ground control points and specify the known geographic co-ordinates. With at least four control points inputted for each digital image, all the related digital images are geo-referenced to a known common co-ordinates system and exported to a common KML file formats. With a geographical visualizing platform, all the related spatial information can be integrally studied.

2.2. Creation of an interactive platform for Spatial Thinkers

We provided various geo-spatial data resources and developed software tools for the teachers / students to integrate geo-spatial data related to an enquiry study into a single platform using Google
Figure 1 (a) User Interface FKML Software; (b) Geo-referenced Images in Google Earth™

Earth™ or other geo-spatial visualization tools. Spatial thinkers can then carry out various forms of explorations and identify the underlying spatial relations (i.e. geography knowledge) among the data.

Follows are some simple yet remarkable examples showing the potentials of the integrated geospatial data platform. All the examples below were initiated by frontline teachers and developed jointly by the teachers and the project team.

Example 1: 3D Visualizations and What-if Analysis.

The first and most powerful function of the geospatial data platform is visualizing and exploring geospatial data in three dimensions. Teachers and students can freely explore the “location”, “conditions” and “connections” among spatial features easily. This function also provides an interesting interactive learning environment as well as strong visual impacts of the analysis to the spatial thinkers. For example, there is a place called Tai O in Lantau Island which is a flooding black spot of Hong Kong. Students are asked to explain the reasons behind the frequent flooding in Tai O.

Figure 2: Tai O as seem in 3D Visualizations
With the three-dimensional visualizations, students can quickly describe Tai O locates in the West of Lantau Island and is surrounded by mountains in all directions (i.e., location). Tai O is also a small village and, according to other data, is a tourist attraction as well (i.e., condition). Finally, as surrounded by mountains, large amount of surface run-off flow to Tai O through mountain streams (i.e., connection) in occasions of heavy rain. Junior form students can also acquire a better learning experience understanding the relations among topography, contour line, stream and watershed etc.

Several types of what-if analysis can be performed easily in the three-dimensional visualization systems. For example, students can create a water body and assign the different water levels with respect to the ground. The students can see “What is the extent of the flood area if the level of water reaches 4m?” Similar analysis can be performed to understand the visual impacts of flooding if a particular building or urban plan is built or suggested.

Example 2: Overlay Analysis.

Another example for IES is the problem of landslide in Hong Kong. Landslide is a serious threat to Hong Kong’s slopes during the raining season. In this example, students are asked to suggest any possible causes of landslides and search the related geospatial information from the Internet. Most of the following materials can be found from the Internet and textbooks easily, including Map of landslide black spots in Hong Kong; Monthly rainfall; Geology of Hong Kong; Vegetation cover of Hong Kong; and Slope of Hong Kong (provided by the Project Team) etc.

Students can suggest a list of factors affecting the occurrence of landslide, which could be imaginary or sensible. Most information in geospatial formats (e.g. maps) can be found from the Internet easily. The technical problem is that the information sources are isolated and their spatial relationships can hardly be identified. Hence, with our developed software as discussed in the previous section, all related information could be geo-referred and integrally studied in the common geospatial data platform. With simple computer skills and operations, our spatial thinkers can apply “association” and answer the following questions, for example: Does landslide occur mainly in steep slopes (or any other factors e.g. rainfall, geology, vegetation cover etc.), are there any exception (association and exception)? Are there any spatial patterns associate with the landslide black spots (pattern)? Are there any landslide black spots influenced by the nearby urban development region (aura and region)?

Figure 3. What-if analysis: What if the level water reaches 4m?
Example 3. Spatial Pattern Analysis.

Geospatial data as well as field-collected data (e.g. GPS data) could be integrated in the data platform such that students could identify if there is any significant spatial patterns as well as their associations with other factors. One example of the urban development pattern in Southern China was developed by our partner school. Satellite Images of the Pearl River Delta (PRD) of Southern China in 1990 and 2004 were given to the students. Students can visualize the growth in urban areas in the last fifteen years (spatial process). With guidance from the teachers, students can further identify the trend of urban development of Guangzhou and Shenzhen in the Pearl River Delta region. Furthermore, students can overlay the satellite images with the road network. One can discover that the growth for the new cities such as Dongguan and Foshan actually follows the pattern of road network (spatial pattern) in the region.

3. Conclusion

The Project developed a pedagogy of implementing GIS & RS in ordinary classroom. We assisted teachers developing tailor-made teaching materials and encouraged teachers / students exploring spatial relations among spatial data and practicing spatial thinking skills freely. The major breakthrough of our
approach is incorporating GIS & RS in classroom teaching on a “bottom-up” basis, in which frontline teachers take the initiative in design and implementation. Teachers’ professional knowledge, creativity and understanding of their students can be fully integrated with the teaching plan.

Back to our initial design principle: “In secondary schools teaching, GIS should mainly act as a platform integrating knowledge and facts of various subjects, provide simple tools to study the inter-relations among the collected facts, combine the observations with taught knowledge and explain / draw conclusion for the study accordingly.”

The Project Team attempted to implement the foundational principle by: 1.) Developing simple software tools to integrate map, satellite images and aerial photographs, as well as GIS data into a common geographical data visualization platform (e.g. Google Earth); 2.) Teaching the frontline teachers to exploring the spatial relations among map-based data within the platform; 3.) Encouraging and assisting the teacher to implement the skills in their interested topics and actual classroom.

More than 90% of participants agreed that the deliverables are valuables in the actual classroom teachings. The actual implementations also suggested that the deliverables could be applied in different contexts of geography teaching. We concluded that the pre-defined objectives for the project are achieved to a large extent. Firstly, The deliverables (e.g. software, web-based resources, teaching materials etc.) are teachers / students- friendly and most participate can use and develop their own lesson with 1 – 2 days training. Secondly, students can use the software tools to explore spatial relations in a half-hour-lesson, they are then encouraged to explain the facts and relations as identified from the spatial data, with their knowledge and understandings on the topics. The focus is shifted from computer instruction to acquire knowledge. Lastly, the deliverables lower the technical barrier of transforming students’ creativities and teachers’ professional knowledge into GIS / Remote Sensing learning activities. Teachers and students can suggest creative perspective to the issue, collect data easily from the Internet and apply simple skills integrating new data to the spatial data platform and explore the relevance of the new perspective to the core issue.

We believed that the developed GIS & RS platform possesses unique contributions to “bottom-up” geography teaching using GIS. Although our developments were based on the situations in Hong Kong, our approach can be referred by educators worldwide, especially for teachers of developing countries where full-function GIS software are hardly accessible. In the subsequent stages of the project, we would implement the pedagogy in more schools and conduct a comprehensive survey to measure the actual benefits of our approach and finalize the pedagogy accordingly.

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Reference