

Applying Problem-Based-Learning to teaching GIS in Higher Education

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Abstract

The GIS Laboratory of the University of Malta was set up in 1996 and has since then provided teaching to students and academic support to staff in a number of departments within the University on the concepts and application of Geographic Information Systems. The objectives of this paper are to (a) identify the key elements and concepts which should be included in an introductory undergraduate GIS module; (b) identify the problems of teaching multi-disciplinarity in the application of GIS at undergraduate level; and (c) discuss the role of student self-learning by applying problem-based-learning techniques in GIS.

1. Introduction

The process of developing undergraduate GIS modules is made up of a number of stages. This paper aims at

- identifying key elements of an introductory GIS module;
- identifying the problems of teaching GIS at undergraduate levels to various disciplines; and
- discussing the importance of student self-learning by applying Problem-Based-Learning techniques in the application of GIS.

The University of Malta is the oldest and highest educational institution in the islands with some 10,000 registered students following full-time and part-time degree and diploma courses. The Geography Division is part of the Mediterranean Institute – a multidisciplinary institute for social science and arts subjects. The GIS Laboratory has been linked primarily to the Geography Division since the coordinator forms part of the Geography faculty.

The University of Malta has, since 1996, supported the setting up and maintenance of a GIS Laboratory with the assistance of the Environment Systems Research Institute (ESRI). The Lab was opened in 1996 and since then has continued providing GIS education and skills to a variety of students in different departments and faculties. Starting originally with Computer Science and Geography, the laboratory has now expanded its teaching to other departments, mainly Archaeology, Biology, Engineering, Architecture and Education.

Apart from teaching, the Lab also supports research by providing the hardware and software facilities and technical expertise to a number of groups. The major support however is given to student research and the use of GIS in dissertations and research projects. Once under-graduates obtain basic knowledge of GIS concepts and use, they are strongly encouraged to use GIS in their research, being it coursework throughout their degree program or in their final year dissertation.

The results so far have been encouraging. Over the years, geography students have increased their employability by having GIS skills. In 2004, 20 per cent of the geography degree graduates were directly

employed in GIS in various fields such as agriculture, transport and mineral resource management. This has increased the visibility of Geography as a subject in the local job marketplace [1].

The experience gained in tutoring, research and administration will be presented in this paper in support of the objectives set out for this paper.

2. Key elements of an introductory GIS module

Despite many disciplines embracing spatial analysis, geography departments in higher education institutions still play a dominant role in the teaching of GIS [2].

The introduction to GIS is a crucial point in the student's undergraduate years. Amongst the factors that will influence his/her career decision whether to become a GIS specialist or simply a casual user, is the understanding of the main concepts of a GI system. Today, there are a number of help tips on the Internet which point any newcomer to the teaching of GIS in the right direction. But setting the course structure is only one element of an introductory module. Other factors come into play when preparing for the academic year. This section will be dealing with some of these elements including:

- understanding your audience
- main components of an introductory GIS structure
- coordinating lectures and practical sessions over a relatively short period of time
- use of teaching aids for higher education

2.1. Understanding your audience

With today's varying degree of computer skills in a class, particularly of digital cartography, it is very difficult to gauge your audience's adaptability to understanding and using a GIS. Most students outside the computer and IT studies which come from the Arts and Social Science faculties have background knowledge of Office tools and some basic computing. Having prepared courses for Geography, Archaeology and Biology students, it is important to understand in the early days of your module the computer literacy of the class. Ideally students should have a basic knowledge of databases (tables) and information systems or have been exposed to database software and Computer-Aided Design (CAD) to understand the structure of a GIS.

In the case of non-geography classes the spatial relationships (spatial thinking) must be explained at length before any attempts are made at explaining the concepts of a GIS. It might be useful at this stage to explain the importance of geography in certain fields of study. Non-geography classes have difficulties to understand the applicability of GI systems because of a lack of understanding about spatial relationships and the value of spatial data.

It may be helpful to separate classes according to their backgrounds. Biology students are taught separately from geography students because the case studies used to explain certain concepts are different. Students can relate much faster to a subject which falls under their subject specialisation. Many websites today provide examples, such as the use of GIS in the 2004 Tsunami disaster (Figure 1.). Getting students to explore what is available on the Internet is a valuable starting point.

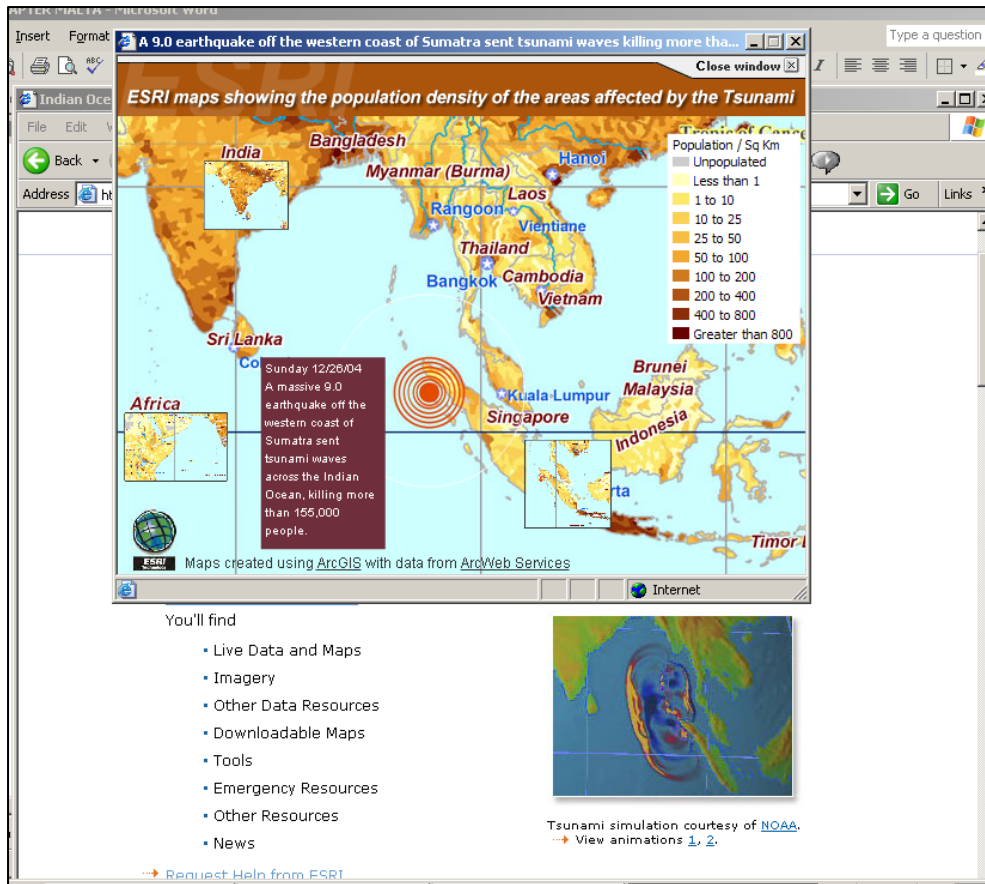


Figure 1. Applying GIS in the Indian Ocean disaster. Source: http://www.esri.com/news/pressroom/indian_ocean_disaster.html

With an increasing multi-disciplinary approach to university studies, it is becoming very difficult to have homogenous groups of students. There will be different backgrounds, varying degrees of computer skills and a different understanding of what spatial relationships are. However, if these elements are understood they can be used in the class to assist in the progress of the individual, particularly in applying the Problem-Based-Learning approach through team work. Once the nature of the audience is established, the next step is to try and identify the important components of a GIS module, which are necessary for the students to start using such systems.

2.2. Main components of an introductory GIS module

In one semester of an undergraduate course, there is an opportunity for introducing both the theoretical elements of a GIS and practical use of GIS software.

Over the years, the course structure of the introductory module in GIS at the University of Malta has changed to reflect the needs of the students and the constraints of their degree programmes. In some

cases, the aim of the programme is to learn GIS skills rather than learn the science. Others dedicated only few hours of a wider skills module dealing with spatial analysis tools (including remote sensing). Also as students become more conversant with computers, teaching basic computing became redundant. Originally, the module covered aspects of history and GIS development, map projections, image processing, data collection and storage, applications and digital terrain models. Over time, this structure was simplified to allow students more time for interact with the software and work on their projects (problem). The most important elements for direct tutoring in class have now been rationalised to four main topics. These elements are structured in a way to cover half the time of a semester (see Table 1 for a typical course structure)

Topic	Description
1. Introducing GIS	Definitions, history and development [internet and literature review]
2. Spatial Data	Concepts, Types, Sources and Quality Issues [handling data in ArcGIS]
3. GIS functionality	Data Capture, Structure, Manipulation, Analysis and Output [data capture, analysis and output in ArcGIS]
4. GIS implementation	Applications of GIS [team project and written test]

Table 1. Structure of an undergraduate GIS module.

There is a good review of these concepts in introductory textbooks such as Heywood et al. [3], Clarke [4] and the GIS Dictionary published by Wiley [5].

In the first session where students come into contact with the concept of GIS it is very important to start with definitions of GIS and how the systems developed out of Computer-Aided Design (CAD) and Information Systems (databases). This should be supported by specific examples of applications to which students can relate and understand. Going through the history of GIS developments also helps to understand the definitions and where the technology is coming from. At this stage it is useful to provide the students with some initial websites to start them on web resources. Some might include:

- a first introduction to Geographic Information Systems (<http://www.gis.com/>)
- the GIS Timeline website for the history of GIS (<http://www.casa.ucl.ac.uk/gistimeline/>);
- the Geography Network website for the creation of maps using ArcExplorer (<http://www.geographynetwork.com>);
- an overview of map projections (http://www.colorado.edu/geography/gcraft/notes/mapproj/mapproj_f.html)

- academic publications of a research centre specialized in spatial analysis (<http://www.casa.ucl.ac.uk/news/index.htm>)

Due to the importance of data in GIS, two sessions are generally dedicated to data concepts. These cover aspects such as different data structures used in a GIS and their characteristics, data types and availability, data sources and most importantly the issue of data quality. Students must be made aware of the issues of data quality from an early stage. Data must be checked for its timeliness, attribute accuracy, consistency and completeness. All this information should be attached in the metadata which is now becoming common practice for any type of data (whether it is spatial or non-spatial).

In order to appreciate what a GIS can do when compared with other mapping software or databases, all its functions must be explained in detail. The third topic covered by the theoretical sessions of the undergraduate study module be accompanied by real time demonstrations of how a GIS functions. These main concepts of a GIS are:

- data capture and input
- system structure and data handling
- data manipulation
- analysis and query
- GIS output and visualization techniques

These concepts are explained individually to build a comprehensive overview of what a GIS can do. At various stages of the course, the student must be supported by demonstrations on a GIS software (e.g. data input through digitisation).

Finally, the module concludes with examples of applications of GIS in the real world and the methods used in implementing a GI system. Apart from the more traditional GIS applications, this aspect could be supplemented with further Internet-based examples such as the lists of industries making use of the technology (<http://www.esri.com/industries.html>). In addition to internet-based information, there are now also textbooks dealing with the management of GI systems [6] for the students who wish to undertake this line of expertise.

Refining these introductory components and their delivery is an on-going process. With increasing computer literacy and accessibility to the Internet, some of these topics become redundant. However, the four main components listed are deemed to be the most relevant to help the student grasp the basic theory of GIS, understand what the system can do and then to apply it more efficiently.

2.3. Coordination of information and practical sessions

Depending on the resources available for the study of GIS within a particular faculty or university, and the time allocated to the GIS module, it may be possible to divide the introductory course into theory and practical sessions whereby students get hands-on experience of the system. In the course planning stage, there should be a clear definition of the hours dedicated to theory and the student hours dedicated

to practical sessions. Practical sessions could be organised around fixed time periods (class based tutorials) or organised around the student (independent) time at home or in the computer laboratories.

Researchers have long argued that effective learning is achieved through a certain degree of learner control [7] [8]. Students should be given the freedom in the choice of problem and by working independently from a tutor [9]. By the end of the module students find that they have ownership over the process of problem solving, the problem itself and what they learn.

Since in most cases, practical session outputs are used for assessment purposes, students are encouraged to dedicate more hours to the use of the GIS software. These study hours provide an indicative measure also of the importance of different course components and give opportunities for meaningful assessment, related to specific learning outcomes.

Within the framework of four ECTS (European Credit Transfer System) credits, the GIS module covers for 20 hours of tutor contact and another 40 hours of student independent study on a project. During the theoretical part of the module, students are introduced to the main concepts and demonstrations on GIS software. During this period students are required to review a list of textbooks, journals and internet sites provided at the beginning of the year. During the first few weeks, students are required to develop a project (define the problem to be studied spatially), prepare a brief description of the project, the data required and the team members (2-5 students).

Once the student projects are discussed and approved, the students then have to collect the information from the field (when necessary), input the data using any input methods necessary. Once the system is populated with information, the students start the process of querying the data. This process is generally covered with the remaining contact hours and students experimenting with the GIS software in their own time. In addition, the students are required to write up a short report on their experience using GIS. The final report is generally structured in the following manner:

- introduction to GIS
- project proposal
- methodology
- analysis
- problems encountered
- conclusions and applicability of GIS in the project

The map outputs and the report are done in the student's own time and generally submission is requested towards the end of the semester. A written test concludes the module.

The use of problem-based-learning in the teaching of GIS has many advantages. These include improved spatial thinking, better adaptability to problem solving, faster learning, and longer than expected use of GIS software for final year projects or further studies.

2.4. Use of teaching aids for higher education

There are a number of useful teaching aids for supporting GIS learning in higher education. The fact that GIS is a relatively young technology and most advances in the system have been recorded and are

available on internet is probably the most useful aid. Conference papers, journal articles and now even books are available for download from the internet at some of the most popular GIS sites (see for example <http://www.wiley.com/legacy/wileychi/gis/volumes.html> for the complete book contents of [10]). Wiley and Longley *et al.* have teamed up to present an online teaching aid for both teachers and students. This includes an instructor's manual, presentation slides and case studies to use in the classroom.

Another invaluable resource is the ESRI Virtual Campus which is an online training site for learning ArcGIS (<http://campus.esri.com/>). This site is particularly useful for students who wish to use particular software and find no training available locally. Also on this website there is access to a Library which allows student to browse conference proceedings, books, journals, magazines and reports. This is a useful tool for students to prepare for their practical research projects and any summative assessments at the end of the module.

Some textbooks also provide self-learning tools with software demos and case studies and students should be encouraged to invest in one of these textbooks to get as much hands-on experience as possible. Specific textbooks relate to particular software and even though the technology develops over very short periods of time and such books become dated, it is always useful for students to undergo independent learning on GIS software (see for example [11]).

3. Teaching undergraduate GIS to various disciplines

The GIS Laboratory is a multi-disciplinary centre for the teaching of GIS within the current structure of the University of Malta. The academic staff falls under the umbrella of the Geography Division but it provides courses and consultation to numerous faculties, institutes and centres at the University. To this end, a number of modules are delivered each year, particularly the undergraduate introductory GIS to provide opportunities for those studying different degree courses and academic disciplines. These modules are not combined due to their specificity and the need for a discipline related focus. One example is the different module title assigned for the teaching of GIS to biology students.

The major problem of teaching GIS to various disciplines is the instructor's disposition to the different applications of GIS in their field. Despite students having a fixed structure to follow at the beginning of the course, some of the more professional degree courses have industry specific requirements which the teacher should be aware of. In the case of Architecture and Education, expectations by the industry must be understood before undertaking development of any module in GIS.

Fortunately for most disciplines there are both textbooks and exercises which can help tutors to use industry specific case studies. In the case of Education there are particular textbooks which guide the teacher to various levels of GIS education in schools (see for example [12]).

The flexibility of the GIS tutor must be one which encourages the application of GIS in various disciplines. It is also advisable to have the GI science separate from the system parts of GIS teaching. Two members of staff should be appointed to deal with these two elements of GIS, particularly for advanced courses.

Development of a GIS Lab or centre should focus on attracting various disciplines. This however might be a problem particularly in the period during which courses are being set up and students are attracted to take modules in GIS. A long term plan for the development of GIS training is crucial to ensure both professional and course development is constant.

4. The role of the student

As discussed earlier, the student has a very important role to play in the delivery and success of GIS modules at undergraduate level. This is affected by the student's adaptability to use computer software and the amount of practice one is willing to put in during and after the module. A problem-based-learning approach is applied at the University of Malta.

Problem-Based-Learning is defined as learning by doing [13]. Students are stimulated to formulate their learning goals and reflect on the quality of their learning, the process as well as the outcomes [14]. They work in a group and self-assign tasks and roles. The tutor, on the other hand has a coaching role in over-seeing the learning of the students. Today's society, characterized by information exchange, internet and increasing dependence on technology, requires graduates able to work in knowledge-intensive environments, and particularly in teams [15]. Educational research has shown that problem-solvers are organised and flexible, and are able to apply knowledge for problem solving [16].

The student is therefore encouraged to seek a spatial problem for investigation. Here students are allowed the freedom to choose any topic and depending on their subject specialisation and exposure to computer use, the project is defined through a brief project description.

The adaptability to use computer software depends on the student's background subjects in secondary and post-secondary education. In the case of Malta, geography students are not exposed to computer science. The GIS module in the undergraduate programmes provides an opportunity for students to use the software, but not to develop much interest in GI Science.

It is however easier for geography students to understand science, than science students to understand the applicability of GIS for spatial analysis. This is evident from the student projects submitted over the years. Whilst geography students can visualize a whole project and probably manage it better, computer science students generally focus on one aspect of GI science, such as visualization or data structures, without much care for application and effectiveness of decision-support. It is important to encourage both as in the work environment both technician and applications manager need to work side by side to build a GIS. This skill is a necessary learning outcome of a GIS module at undergraduate level.

Students should also understand the importance of hands-on experience (the Problem-based-learning approach). Most students today are keen at using the software from an early stage of the study unit. It is important however that during the first tutorials the tutor is ensuring students understand the processes that are going on in using the software. There is a tendency for students to quickly go over the initial tutorial exercises without understanding why and how they are doing such exercises. This jeopardizes their future ability to use and apply GIS.

In assigning student working hours per credit, students undertaking a GIS module must ensure they understand the different functions of a GIS. This is today possible with the availability of software at the university and even at home. Evaluation software or free downloadable software (such as the case of ESRI ArcExplorer) from the internet, allows students to explore the basic functionality of GIS.

It is also important for the student to take interest in seeing how systems are operated in the real world, and in the case of Malta this is possible with site visits to particular industries which have applied GIS in their work processes. A number of major organizations now run GIS such as the Malta Environment and Planning Authority, which also has an internet map server [17], Water Services Corporation, the Department of Agriculture and the Malta Transport Authority. These provide opportunities for students to visit live systems and enquire about possible employment opportunities in the field.

In conclusion, the role of the student in learning about GIS is very important, particularly when GIS is taught as part of a whole catalogue of modules in topics such as geography. The high visibility of GIS on the internet provides most of the information and exposure required by students to understand the basic concepts and make an informed decision on the importance of GIS in the workplace.

5. Conclusions

This chapter aimed at identifying the opportunities and problems of developing undergraduate study units for the teaching of GIS. The experience gained through the teaching years at the University of Malta, have been used as a case study. The chapter has focused on the course development and problems of multi-disciplinary teaching but also on student aids and the importance of self-learning.

The demand for geospatial skills is growing worldwide (see [18]) with more scientists required to understand the processes of integrating use of GIS with spatial phenomenon. This on its own should be an incentive for higher education to invest in the teaching of GIS at undergraduate levels.

In the case of Malta, perseverance to provide for the GIS Lab and the courses to undergraduate students has started to show the first signs of success. The increasing market demand for these professionals will in time mean more opportunities for the students to find jobs and further specialize in this field.

With these results, the University of Malta is now more adamant to invest and encourage GIS in the undergraduate and hopefully soon in the postgraduate courses it offers.

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