Teaching GIScience with Free and Open Source Software? – A first Assessment

S. Steiniger[1,2], A. J. S. Hunter[2]

[1]Department of Geography, University of Calgary, 2500 University Drive NW, Calgary, Canada
Email: ssteinig@ucalgary.ca

[2]Department of Geomatics Engineering, University of Calgary, 2500 University Drive NW, Calgary, Canada
Email: ahunter@ucalgary.ca

1. Introduction

Teaching GI-Systems and GI-Science (GIS/c) in geography and the environmental sciences is in our experience most often designed around using proprietary GIS software packages. In the past this has been (correctly) justified given the technical superiority of proprietary software with respect to functionality offered by proprietary solutions, the user friendliness of their interfaces, and also demand from industry for graduates that know a particular (or widely used) GIS software product. However, over the past decade there has been a concerted effort to develop and improve free, i.e. non-proprietary, desktop GIS software products (Mitasova and Neteler 2004, Sherman 2008, Steiniger and Bocher 2009, Donnelly 2010). Furthermore, web-based GIS and mapping applications have been widely adopted in industry, requiring GIS/c teachers to consider and evaluate a new set of GIS software products for teaching (OpenGeo 2010).

From a pedagogical perspective, many contemporary approaches to student instruction such as peer response groups (Walvoord 1986), collaborative learning (Davis, 2001), and alternative perspectives (Grasha, 1990) regularly parallel elements of open source approaches. As such open source solutions and the philosophies that they are built upon can act as both a metaphor and a method to provide students with a practical way to collaborate and learn.

Subsequently, we see a need to assess free software products for their use in GIS/c teaching, which will not only include an evaluation of functionality and usability, but also include an analysis of benefits and limitations that emerge from open software licenses. With this assessment we hope to give answers to the following two questions: (i) can proprietary software be replaced by free GIS software for teaching GIS/c? – and (ii) what are the strengths and weaknesses of using free software for teaching?

2. What is 'free' software?

There is sometimes confusion about what 'free' software actually is. The term 'free', as used here, refers not to free-of-cost, but to freedoms granted to the user by the software license. These freedoms include the right to (i) run the program for any purpose (e.g. educational or business use); (ii) study the program; (iii) freely copy and distribute the program; and (iv) modify the program, and distribute the modified version (see the Free Software Foundation webpage: FSF.org). Note that these freedoms do not prohibit selling a program. Hence, the opposite of 'free software' is not 'commercial software' but 'proprietary software', which stresses ownership. Typical free software licenses such as the GPL, LGPL, Mozilla, Apache, MIT-style and BSD-style licenses grant these four freedoms.

3. Software Requirements for Teaching GIScience

3.1 Case Studies

Several articles compare free GIS software either against other free GIS software or against proprietary software. In particular, Donelly (2010) evaluates free GIS software for the creation of maps within a library environment. He concludes, based on the comparison done in 2008, that free desktop GIS are weaker, compared to ArcGIS, with respect to projection and coordinate systems support, joining tables and labelling. Steiniger and Bocher (2009) discuss the state of free desktop GIS and outline its utility for GIScience research in comparison to proprietary software. Hengl et al. (2009) compare free desktop GIS GRASS and SAGA for automated elevation data analysis, and Jolma et al. (2008) and Steiniger et al. (2009) analyse and compare free GIS software for its use in the environmental sciences.

Our analysis is based upon three courses that are taught to geography and geomatics students at the undergraduate level (i.e. BSc) at the University of Zurich and the University Calgary. Two of the three courses utilize lectures and exercises to cover introductory and advanced GIS/c topics for 2nd and 3rd year students, subsequently denoted as GIS I and GIS II. The third course is a GIS project course, in which a group of (approximately five) 4th year students are tasked with a web GIS implementation – i.e. a web GIS map.

3.1 Software Requirements

For the three courses we analysed the following: (i) the course setting (i.e. infrastructure) – to define general constraints with respect to course administration etc; (ii) general course objectives – to define software features (e.g. license, usability, customisability, etc.) that support teaching, and (iii) the course content with respect to lecture and tutorial topics – to obtain a list of required software functionality. The results of our analysis, i.e., GIS software requirements, are presented in Figure 1.

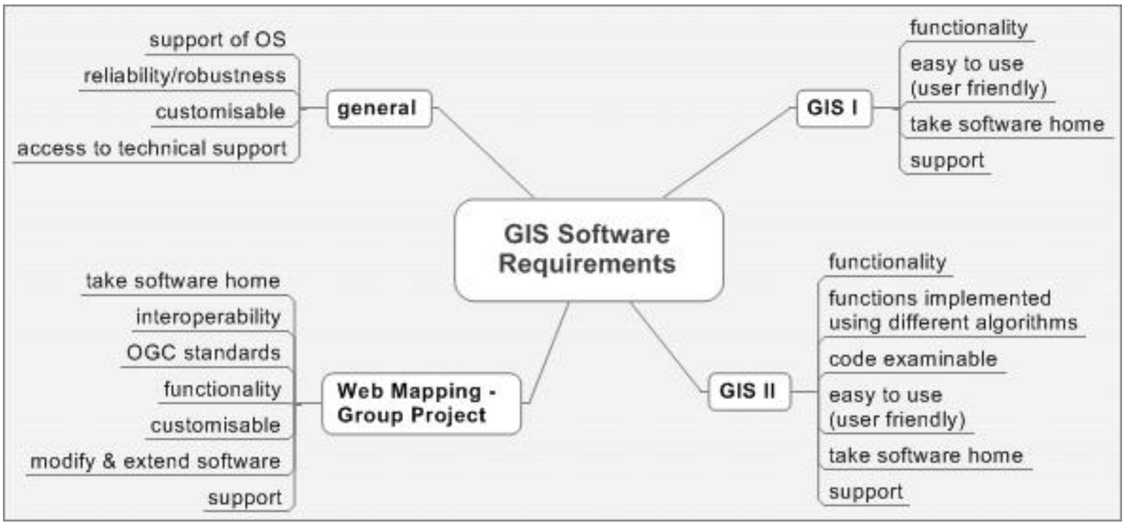

Figure 1. Software requirements for teaching selected GIS/c courses.

4. Software Analysis Results

To determine which software qualifies for teaching these courses we evaluated several free GIS with respect to their functionality. For the GIS I and II courses desktop GIS software was used, whereas the GIS group project required several types of software to build a web GIS system. The functional assessment for desktop GIS also included the proprietary software ArcGIS, as this software is currently provided by the universities and is generally used for all GIS exercises. Table 1 presents the results for three free desktop GIS due to space restrictions. Other software that may qualify with respect to functional needs might include: ILWIS Open, gvSIG with the Sextante Toolbox, and SAGA (see also Steiniger and Bocher 2009, Hengl et al. 2009). For the web mapping project we do not present a detailed functionality assessment but list software that provides the needed functionality in Table 2.

Table 1. Software functionality evaluation for teaching GIS I and GIS II courses.

function	Course Level	ArcGIS	GRASS	QGIS	OpenJUMP	function	Course Level	ArcGIS	GRASS	QGIS	OpenJUMP
Raster/vector data	I	•	•	•	•	Carto. Projections	I	•	•	•	p
Create a map	I	•	•	•	P	Vector-to-raster	I	•	•	G	S
Query attributes	I	•	•	•	•	Raster resampling	II	o	•	G	S
Query distance	I	•	•	•	•	Reclassify	I	o	•	G	S
Query DE-9IM	I	•			•	Geom.-type change	I	o	•	•	•
Creating geom.	I	•	•	•	•	Geom. Simplify	I	o	•	•	•
Edit attributes	I	•	•	•	•	Landscape indices	I	p	•		S
Table/txt joins	I	•	•	•	•	Thiessen polygons	I	o	•	G	•
Basic statistics	I	•	•	•	p	Slope	I	P	•	G	S
Thematic maps	I	•	•	•	p	Contouring	I	P	•	G	S
Polygon overlay	I	•	•	G	•	Curvature	II	P	•	G	S
Zonal statistics	I	o	•	G	•	Flow direction	II	P	•	G	S
Map algebra	I	o	•	G	S	Flow accumulation	II	P	•	G	S
Multi-Criteria-Eval	I	o	P		S	Watershed	II	P	•	G	S
Sliver removal	II	o	•	G		Compound indices	II		•	G	S
Geom. Union	II	•	•	•	•	Viewshed	II	P	•	G	S
Geom. QA/cleaning	II	•	•	•	•	Hillshade	II	P	•	G	S
I:IDW	I	o	•	•	S	Profile graph	II	P	•		S
I:Spline	II	o	•	G		Extract raster vals	II	P	•	G	S
I:Contours to DEM	II	o	•	G		Fuzzy sets	II	o[2]	R		S
I:Kriging	II	o	R		S	Change matrix	II		•	G	
Kernel Density	I	o	R		S	Spatial indexing	II		•	•	•
Georeferencing	II	•	•	•	S	SQL	II	•	•	•	•
Metadata editing[1]	II	•				Scripting/Modeller	II	•	•	•	•

• functionality provided, o functionality provided with ArcGIS ArcInfo, but not with ArcView, P: separate plugin/extension, R: GRASS with R, G: QGIS with GRASS Toolbox, S: OpenJUMP with Sextante Toolbox, [1]a free metadata CatMDEdit exists, [2]Fuzzy overlay will be included in ArcGIS 10

5. Discussion – using free GIS software for teaching?

5.1 Strengths

Points that speak for the use of free software in (undergraduate) teaching emerge from at least three software related perspectives: i) software functionality & features, (ii) the software license, and (iii) organizational aspects of a software project. With respect to

Table 2. Free software that can be used for the web mapping group project.

Software Type	Purpose	Software
Web map server	Create & serve map	MapServer, GeoServer, etc.
Spatial DBMS	Store data	PostgreSQL with PostGIS, SpatialLite, MySQL
Development Frameworks	Scripting/programming environment	Aptana/Eclipse, jQuery, AJAX, etc.
Web map development toolkit	Functionality for client (map) interaction	OpenLayers, GeoExt, GeoMoose, MapFish, Mapstraction, etc.
Desktop GIS	Data editing/preparation	see Table 1

software functions and features, it is apparent from the results in Section 4 that the evaluated software, QGIS with the GRASS toolbox and OpenJUMP with the Sextante toolbox, fulfil almost all functional requirements for the GIS I and II courses. In addition several free software solutions for the web GIS projects exist. Other positive pedagogical points include: (1) different algorithms for the same function are implemented (e.g. several slope algorithms in Sextante), which allows students to directly compare results of different methodologies, (2) desktop GIS are customizable and provide scripting support, (3) user interfaces have become more user friendly, and (4) free GIS software often supports a range of OGC standards, allowing for interoperability between the components of a web mapping system.

Positive aspects that emerge from the free software licenses include: (1) the software can be taken home, (2) students have access to code to learn aspects of algorithm implementation and process flow, (3) the software is modifiable, and (4) its acquisition is often free-of-costs. Furthermore, and with respect to organizational aspects, free-of-cost and in-time support for free GIS software can be obtained by email and internet forums. Paid hotline support and training courses also exist.

5.2 Weaknesses

Before adopting free GIS software for teaching there are some points that an instructor should be aware of: (1) not all functionality needed for demonstrating certain GIS/c concepts may be available via a single desktop solution without the aid of additional plugins, (2) the quality of software documentation, i.e. user manuals, varies among projects – and it's publication may not match software releases, (3) similar to proprietary software, free software also has associated indirect costs, such as the cost of switching to free software, the cost of training staff, and maintenance costs.

Other points that are not directly related to the software itself may also be important, but are not necessarily weaknesses of free software. For example: (i) ArcGIS employs different terminology from that used by common GIS standards such as OGCs Simple Features Specification – particularly with respect to overlay functions. (ii) There is in general no, or little marketing for free software. That is, a user needs to inform oneself of software upgrades, etc. (iii) Finally, it is unclear how industry welcomes students that have been trained with free software and not, for instance, with ArcGIS or Geomedia. Although we note here that according to our experience GIS companies show a strong interest in making use of free GIS software. Further points on options and threats when using free GIS software in teaching can be found but are discarded due to limitations in space.

6. Conclusions

With respect to the use of open source GIS software for teaching, we believe that free software has achieved a level of maturity that enables it to replace proprietary desktop GIS software when teaching GIS I & II level courses. The software projects we have reviewed appear to be stable and reliable; however for other software projects one should consider the maturity of the project before adoption. With respect to course projects that focus on web GIS development, we see no strong proprietary alternatives to using free software. In addition, free web GIS solutions are generally more agile in their ability to adopt new web technologies and standards.

In addition, when focusing on a web GIS development project, an instructor who uses open source software would be able to extend projects from a single semester to multiple semesters such that projects are built and incrementally developed from semester to semester. This would enable students to see themselves as part of a larger body of work rather than as solitary implementers of one project. As posited by Faber (2002), this should teach students about the interdependence of project-based work and how their own work fits within larger frameworks and communities.

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