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Teaching practical science online using GIS: a cautionary tale of coping strategies.

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Abstract

Strong demand for GIS and burgeoning cohorts have encouraged the delivery of GIS teaching via online distance education models. This contribution reviews a brief foray (2012-2014) into this field by the Open University, deploying open source GIS software to enable students to perform practical science investigations online. The 'Remote observation' topic spanned four science disciplines in 6 weeks – an ambitious remit within an innovative overarching module. Documenting the challenges and strategies involved, this paper uses forum usage and student feedback data to derive insights into the student experience and the pitfalls and pleasures of teaching GIS at a distance.

(98 words)

Keywords (3 to 6): GIS, distance education, online forum, buttonology

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1. Introduction

Burgeoning student cohorts and high demand for GIS skills is prompting educators to adapt their teaching methods: online delivery, either blended with classroom teaching or purely online, is an obvious strategy. Online courses carry the collateral benefit of the ability to reach a global cohort of students – a potentially lucrative option for higher education (HE) institutions. The drivers for developing online GIS courses seem almost inexorable, as implied by the recent increase in support websites such as teachGIS.org, which were also prompted by the recognition that teaching with GIS “is neither easy, nor intuitive” (Perkins, 2015).

One might assume that the maturing, dominantly digital, technology of GIS would suit distance, web-based learning (Clark, Monk & Yool, 2007), especially within a constructivist framework built around problem-solving activities (Zerger, Bishop, Escobar & Hunter, 2002). The core of the subject comprises software tools, digital data and imagery that can be deployed and manipulated on desktop computer systems, or accessed via the internet. The distance model has been adopted for self-directed postgraduate students, but is less common at undergraduate level, aside from some Massive Open Online Courses (MOOCs), perhaps due to the continuing perception that distance teaching is more onerous (DiBiase, 2000). However, comparing a GIS classroom practical with the corresponding online distance practical highlights some of the challenges for distance teaching of GIS (Table 1).

In this contribution, I outline the initial rationale behind a modest suite of GIS-based teaching materials for part of an Open University module, then track the development and deployment of the study materials, present some evaluation of the student and educator experience, and finally offer reflections on the findings. I hope that my candid record of the shortcomings and successes of this teaching initiative will prove useful to those teaching GIS face-to-face as well as at a distance – though it should be stressed that the primary aim of the module concerned was to teach practical science, *not* GIS.

2. Background

In late 2010, work began on production of a suite of new Open University (OU) 30-credit modules, S288 *Practical science*, an ambitious project to deliver practical science teaching, entirely online, to OU distance students. The 'Remote observation' topic, one of seventeen 6-week topics embedded in S288, was tasked with teaching practical science skills to students in the Geoscience, Chemistry, Physics and Environment disciplines. The challenge was to create distance education materials to

introduce students – most of them with no prior experience of GIS software – to GIS concepts and techniques sufficient to conduct a practical investigation in each of these four discipline areas (Table 1).

The limited study time imposed by the design of the host module necessarily restricted teaching of GIS skills to those essential for the scientific investigations, bypassing some key concepts. The unenviable result was that the students followed a workflow in the software with no time to develop a deeper understanding of *what* they were doing or, indeed, *why* – a classic example of the ‘buttonology’ approach (e.g. Marsh, Golledge & Battersby, 2007; Kerski, 2013; Bearman, Jones, André, Cachinho & DeMers, 2016) where mastering the software dominates the cognitive load (Sweller, 1988).

The Remote observation topic was not designed *primarily* to teach GIS, either conceptually or practically. Rather, GIS was chosen as a convenient tool to enable OU distance students to engage in practical science activities and experiments, in order for them to gain experience of testing hypotheses with real scientific data. The decision that students should use GIS software was made early in the production process, for various reasons:

- GIS software exploits rich opportunities for practical activities that would otherwise be very limited and/or repetitive (e.g. interpreting static satellite images visually)
- GIS skills represent highly marketable assets for students concerned with employability, for instance those starting, developing or shifting careers
- GIS teaching was markedly lacking in the OU distance curriculum compared to other higher education (HE) institutions

3. Strategies for distance teaching with GIS

3.1 Design of materials

As one of the first OU modules delivered *entirely* online via a Moodle-based Virtual Learning Environment (VLE), S288 required considerable innovation, resources and internal scrutiny to produce. The student learning model was firmly at the formal end of the spectrum (Rickles & Ellul, 2014), with extensive scaffolding of the learning journey to aid cohesion (Aviv, Erlich, Ravid & Geva, 2003). The ‘Remote observation’ topic, like many others, deployed specialised software for students to generate and/or analyse primary data in their scientific investigations. So an early choice was: which GIS programme(s) should be used?

The short timescales of the topic favoured a single, cross-platform GIS programme (for consistency across the cohort) that was relatively simple to use. Unfortunately, despite widespread calls for a ‘minimal GIS’ (e.g. Marsh et al., 2007), there was neither a simple, introductory GIS package available, nor a WebGIS (Baker, 2015), that provided all the required functionality. The Open University had recently withdrawn support for Mapinfo (Pitney Bowes, 2011) in favour of the ArcGIS suite (ESRI, 2010), for which it held a site-wide licence. However, this ‘expert practitioner’ software was deemed too daunting for students learning how to use it in 5 weeks, and potentially costly for them. Two open source GIS packages, QGIS (QGIS, 2011) and gvSIG (gvSIG, 2011), bypassed the question of cost. In the event, gvSIG was preferred because at that time all the required functions in gvSIG were GUI-based, and hence more user-friendly for novices.

Using a single programme streamlined the creation of support materials (see below), but open source software develops rapidly: during the module lifetime, at least three new versions of gvSIG were released. To preserve the integrity of the learning materials, it was decided to provide only the 2010 version of gvSIG (v1.10) for the topic, and advise students to use this.

Along with the GIS software, roughly 2 GB of data had to be provided to the students. Wary of variability in students' internet connections (download speeds, limited access; see Elsner (2005)), these data were initially provided to all Remote observation students, along with the software, as self-installing zip archives on DVD. The data were subsequently posted for download on the topic website.

3.2 Static support

Support for distance learners may be categorised as static (built into the learning materials), or dynamic (proactive or reactive support delivered during the period of study). The main components of static support for the Remote observation topic are listed below:

- *'Before you embark on...'* page (heading the topic) warned students of the IT challenges ahead, gave advice on file names and downloading, and summarised the various forms of support available.
- *Comprehensive instructions.* Detailed workflows for all activities, many as bulleted lists.
- *Software footnotes.* Shorthand reminders of common operations in gvSIG, linked from the online text.
- *14 narrated screencasts, with index.* Up to 9 minutes long, these demonstrated essential functions of gvSIG, including software download/install.
- *List of FAQs* (pdf file, 2013 and 2014). List of questions and/or IT 'symptoms', each linked to common causes/diagnoses/solutions.

3.3 Dynamic support

Support during the topic was provided either in response to direct student queries/requests, or emerging issues on online forums, or if the educators anticipated a future problem.

- *Academic support.* Two topic specialists, with GIS expertise and at least a working knowledge of gvSIG, were allocated 1.5 hrs per working day to respond to student queries via the online forums. Each student also had a module tutor, but their support was limited (in most cases) by their lack of specialist (GIS) knowledge.
- *IT support.* Mainly from topic specialists, but also the OU's central IT helpdesk (for generic IT issues).
- *Peer support.* Almost all through the online forums.

4. Evaluation methods

Limited evaluation of the Remote observation topic, prompted by reflections on the first presentation in 2012, was undertaken via two main methods. The host module, S288, only ran for three years (2012-2014).

4.1 Analysis of forum data

Online forums were analysed by collating data from the VLE in spreadsheets. Changes to the VLE platform and OU data retrieval protocols limited a fuller inter-year comparison to the first-order data presented in the Results section, with some more detailed data from 2012.

4.2 Analysis of student feedback

Student feedback was gathered each year via a dedicated discussion thread on the online topic forum. A form of content analysis (Krippendorff, 1980) was used to assign comments to relevant categories (Lauri & Kyngäs, 2005) and then each comment was scored as either positive (+1) or negative (-1) sentiment. (The lack of 'neutral' comments reflects the typically engaged student

cohort, but also the fact that responses were free-text rather than constrained to a Likert-type scale.) Since later posters could see all previous comments, there was the potential for bias in later posts; however, the main manifestation of this was that several later posts cited and affirmed earlier ones, before adding their own emphasis.

5. Results

5.1 *Online forums*

VLE usage data for the online Remote observation topic forums is summarised in Table 3.

A few features of the data in Table 3 are worth highlighting here for subsequent discussion:

- Relative proportions of students viewing and posting on the forums (90% and 46% respectively; 2012 only)
- Proportion posting decreased in 2014, despite much larger cohort
- Total number of posts almost identical each year, despite different cohort sizes.
- Percentage of short threads increased year on year.
- Number of long threads increased 2012-2013, but levelled off in 2014 despite larger cohort.

Graphs of forum usage are restricted to 2012 (Figures 1 & 2), due to VLE data protocol changes. However, these graphs illustrate patterns of forums usage that were broadly similar in subsequent years; principal differences are recorded in Table 3.

A selection of quotes on the effectiveness of forum are included in the discussion section.

5.2 *Student feedback*

Student sentiment (positive or negative) expressed in comments within the feedback thread is summarized in Figure 3.

Figure 3 picks out a few key reactions of students to the topic, which will be discussed later:

- GIS software attracted comparable numbers of positive and negative comments
- The forum support was viewed almost exclusively as positive
- Aspects of the topic viewed negatively included the website usability, general IT issues, online study and overall workload
- In terms of the activities, their scientific content was generally popular, but the perceived 'buttonology' involved attracted substantial negative comment
- The provision of a DVD to alleviate download concerns prompted just a few negative comments
- There was little acknowledgement of the value of the GIS skills taught in the topic to potential employers (employability)

6. Discussion

As one student commented in 2012:

"It cannot have been easy to devise a Remote Observation, group participating, remotely taught, practical module! The learning curve was always going to be steep for that one!"

This experiment in teaching practical science and GIS skills online is discussed below, drawing on the evidence from forum analysis and student feedback.

6.1 Teaching materials

One inevitable conclusion is that the (centrally imposed) remit of the topic was far too ambitious for 6 weeks' study, reflected in the overwhelming response that the topic workload was too high (Figure 3). However, in addition numerous students complained that "...it was mostly just following instructions" – a mode of teaching familiar to many GIS educators as 'buttonology' (e.g. Marsh et al., 2007), with 'cookbook'-style activities (Bearman et al., 2016). This style of teaching was an unfortunate but inevitable consequence of the short time-scale, the variety of scientific content, and the necessarily low level of assumed GIS knowledge as a baseline for the cohort. As one student remarked:

"I did not enjoy this topic as I felt I was mainly working on the software but learned little about the science and experimental method. The images were stunning, but that was about it for me."

Many students felt that the IT aspects dominated the 'science' content, which could only be studied superficially due to time constraints – though a few recognized that IT is essential for modern science:

"I dont mind doing lots of IT if the science behind it has some depth in its explanation."

Several students commented that example solutions – for instance images illustrating several stages in the creation of a processed satellite image – could have been provided, to scaffold student learning and bolster confidence:

"My only real gripe was not having images of what the final product 'should' have looked like."

Most of the screencast videos used different exemplars to illustrate gvSIG processes, so did not reassure students about their specific content. One issue is how to provide such examples: from the start, or from a certain time, or via some student-triggered 'release mechanism'?

Many OU students resented the transition from book-based to online study (as cautioned by Sui & Bednarz, 1999), and indeed all IT-related aspects of the topic (Figure 3) attracted negative comments, with many criticizing the time spent learning/using IT skills:

"This is a science course not an I.T. one..."

A major concern during module creation was that students would struggle to download the 2GB of data and software required for the exercises. However, far more students had difficulties with retrieving the data from the DVD provided (some disks were corrupted) than reported problems with downloading the same data from the website. In later presentations, the download option was offered – in various formats – as a default. Early warnings about download issues, and coping strategies, were clearly heeded by the students.

6.2 GIS tools and skills

Figure 3 shows that the GIS software was almost the only category to attract substantial numbers of both positive and negative comments. Many negative comments condemned the buttonology approach that reduced the science teaching to software training (Section 6.1), reflecting the proportion of students studying from curiosity or interest rather than to develop employable skills. This lack of depth and scientific context demotivated many students, with some commenting that such 'cookbook' instruction was not difficult, but simply tedious (Jadallah, Hund, Thayne & Studebaker 2015).

Providing an increasingly outdated version of gvSIG introduced more problems (e.g. conflicts with updated Java) as the module aged; students who did update reported that they completed the activities with few issues, so in hindsight this advice was misplaced (e.g. Kerski, 2013). Many viewed the software as unsuitable:

"To try to do online learning with what has turned out to be flaky and temperamental software was unwise."

However, some students with experience of GIS or other specialized software countered that even market-leading, commercial software contained bugs, and dealing with the idiosyncracies of niche software was part of modern practical science! Nevertheless, a few students advocated a gentler, phased approach to introducing GIS skills:

“A simpler package (if one exists - I can see changing horses would be tricky) might help, or (depending on available skills since it is open source) a stripped down version.”

“As far as I can make out, Google Earth is a simplified GIS tool. If so, then using this would make a great introduction to the topic as most people are at least familiar with the way it works, even if they haven't used it directly”

These comments echo calls for a ‘minimal GIS’ solution for education (e.g. Marsh et al., 2007), which is as yet not widely available, though web-based solutions are gradually developing.

Positive comments came from students who recognized the power and potential of the software, and in a few cases the skills they had learned, though even these comments were frequently tempered with a wish for clearer warnings of the steep learning curve at the start of the topic.

6.3 Static support

Students were generally appreciative of the various static support features, with the video screencasts garnering substantial positive sentiment (Figure 3). “I have to admit if it wasn't for the excellent 'screencasts' I probably would have given up at the first hurdle” is a typical comment. The videos did not always display correctly or large enough on students’ own devices or systems, and some commented that studying “got quickly frustrating when flicking between the activity page, the video and gvSIG itself.” A few suggested adding parallel pdf documents with images and text, more convenient for viewing (or at least an alternative option).

It is hard to judge the effectiveness of the other static support features, with sparse or no comments on the FAQs and software footnotes; perhaps these were ignored or taken for granted. My experience on the forums was that I frequently redirected students to the FAQs for the solution to their problem. One student commented:

“Sorry: I forget to look in the FAQ section as FAQs seldom contain my Qs.”

6.4 Dynamic support

The forums involved a massive workload for the topic specialists (Figure 2), clearly due at least partly to the large class sizes, which give rise to not only *more* queries overall but also, crucially, a greater *diversity* of problems to be solved. Students were almost universally grateful for both the problem-solving but also the interaction with academics. However, many comments also highlighted informal peer support: the positive role of other students in solving problems (Kear, 2004):

“First, thanks to Tom, Susan and all the people who 'got it' more quickly than I did, for the help via the forum. Yes, it was difficult to find things, but it was great to have such a supportive community.”

“It wasn't just about getting my problems solved (though that was extremely useful), but also the extra insights that I gained from your comments, Tom and Matt.”

Peer support ranged from short messages of encouragement, through brief suggestions of workarounds, to bulleted lists of instructions for a particular task (e.g. measuring the motion of atmospheric features on Jupiter, posted at 15:09 in reply to a question at 13:40 on the online forum).

Managing such numerous forum threads was difficult (Kear, 2001; Welch, 2015). We evolved a rigorous system of subject lines by activity number and ‘keyword’ to facilitate searching (via an excellent Search function). Once problems were solved, the topic specialists edited the thread

subject line with the word RESOLVED to help those with similar issues. Topic specialists worked hard to foster a 'supportive and productive' community (Kear, 2004), which encouraged students to help their peers and suppressed the build-up of negativity that can quickly prove toxic for online forums (McLoughlin & Luca, 2001, p. 51).

Less than half the students posted on the forums (less than a third in 2014), which might indicate a lack of learner participation (Hammond 2005); but this is belied by the fact that 90% of students in 2012 visited the forums, highlighting their value as a dynamic resource:

“Although I never posted a question on the forum, I could always rely on there being a similar problem, and hence an answer here!”

Curiously, the total number of posts was almost constant from year to year, rather than correlating with cohort size, superficially supporting DiBiase's contention that staff effort and class size are not related (DiBiase, 2000). I would suggest instead a kind of 'plateau effect', where the forums approached a notional capacity in each year, limited by some combination of the finite number of tasks (and hence problems?) in the topic and the ability of the topic specialists to respond to posts. Certainly, in the 2013 and 2014 presentations, few 'new' problems were posted and the bulk of forum traffic addressed similar issues to those raised in 2012. Equally, topic specialists felt they were working 'flat out', with forum traffic at the limits of their capacity to respond – but also perhaps of students to assimilate effectively.

Two results suggested that queries were resolved more rapidly in 2013 and 2014 than in the first presentation. The number of short threads increased each year, while the number of long threads (≥ 10 posts) was similar in 2013 and 2014, despite the much larger cohort in 2014. This reflected several factors: development of FAQs, accumulation of experience by topic specialists, growing 'archive' of solutions in previous years' forums, and increased peer support (with larger cohorts).

7. Conclusions

- Blended static and dynamic support, in a mix of formats, will enable the maximum number of students to succeed. Different distance students flourish via different learning styles.
- Clear signposting of the learning journey ahead is invaluable in managing student expectations, especially warning of steep learning curves.
- Distance GIS teaching is particularly susceptible to 'buttonology'. This can be alleviated by:
 - allowing ample time for teaching the material (avoiding 'compressed curriculum');
 - explaining concepts and context: the 'how' and 'why' of GIS operations are essential components of teaching GIS, motivating students and enlivening content;
 - prompting reflection once GIS skills have been acquired, both on outcomes achieved and on potential applications.
- Excessive time constraints will tend to lead to buttonology-dominated teaching, eventually reducing GIS teaching to no more than training in how to use GIS software.
- Too much simultaneous innovation in a module can derail the teaching and learning processes. Individual innovations (e.g. online delivery, specialised software, new VLE) would be better introduced incrementally, to allow the system to flex and adapt.
- Screencasts are appreciated by students, but are perhaps too inflexible for such a dynamic environment.
- Example images would help scaffold student learning and bolster confidence – but a mechanism for providing these at appropriate times should be developed.

- Thoughtful forum management can dramatically improve the effectiveness of this online tool to maximise student learning.
- Don't underestimate the potential impact of peer support, especially in a diverse cohort with experienced distance learners accustomed to helping their peers. Be prepared to encourage and foster it wherever possible!

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Tables

Table 1 Comparing face-to-face with online distance GIS practicals

Feature of practical	Face-to-face	Online distance
Timing	Synchronous; whole cohort present ¹	Asynchronous; cohort fragmented
Study pace	Prescribed or adaptable	Variable
Hardware	Consistent for cohort	Varies across cohort
Software, operating system, platform, network connection	Consistent for cohort	Variable; software conflicts common
Demonstrator(s)	Available throughout session	Not always (or ever) available
Problem-solving by instructor	Reactive, targeted	Typically delayed
Issues arising	Familiar, most easily resolved	Unfamiliar, harder/more time-consuming to resolve
Adaptive('on the fly') teaching	Easy to implement	Awkward to implement
Direct demonstration	Easy to deliver	Difficult to deliver, schedule
Peer support	Available, typically encouraged	May be delayed, requires fostering

¹ Well, on a good day...

Table 2 Outline of Remote observation topic

Section	Content	Skills
Introduction	Basic concepts, software introduction	GIS layer manipulation; navigating; coordinates and projections; RGB images
The Colour of the Oceans	Colour-depth hypothesis; seabed; turbidity and plankton blooms	RGB colours; point query; excel plotting; digitizing; contrast stretching; symbology; line profile; absorption spectra
Planetary Atmospheres	Ozone hole; surface temperatures; Jupiter wind speeds	Using web-based ozone data; rasterization; threshold filtering; vectorization; reprojection; measuring area; line profile; calibration (Excel); measuring length
Earth and Mars	Global topography; erosional landforms; rock and mineral spectra	Colouring DEMs; interpreting histograms; line profile; interpreting shaded relief, stereo anaglyphs; creating RGB composites; contrast stretching;
Charting the Changing Earth	Shifts in vegetation zones on Mt Kenya	Making RGB composites; contrast stretching; unsupervised classification (clustering)

Table 3 Summary of online forum data for Remote observation topic, 2012-2014

	2012	2013	2014
Number of registered students	258	356	814
% who viewed forum posts	90	-	-
% who posted on the forum	46	46	31
Number of discussion threads	302	250	353
Longest discussion thread	46	99	119
Total number of posts	2286	2122	2337
Threads with ≤ 3 posts (n, %)	64 (21%)	75 (30%)	130 (37%)
Threads with ≥ 10 posts (n, %)	36 (12%)	53 (21%)	54 (15%)

10. Figure captions

Figure 1 Stacked column chart showing all visits to Remote observation forum, 2012. Dashed lines mark the official study period for the topic. Pale blue couplets of student columns mark weekends.

Figure 2 Stacked column chart showing all individual posts made on Remote observation forum, 2012. Symbology as in Figure 1.

Figure 3 Clustered bipolar horizontal bar chart summarising student feedback on various aspects of the Remote observation topic. Results for each aspect are plotted as three bars between horizontal dashed lines; each bar records results for one year (top bar represents 2012; see inset).





