Varying the student experience: An embedded perspective on immersive visualisations within the Geographical Information Science Curriculum

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Abstract

This paper explores the pedagogic importance of incorporating varied spaces and perspectives to the student learning experience. By introducing a combination of traditional, visual and active learning environments, our aim is to enhance students' learning experiences and spatial understandings. The work draws on the constructs of blended learning, in which a range of teaching and learning approaches are drawn together in a case dependent manner and implemented in the curriculum to address a number of issues associated with the progression of modern-day educational needs. In our approach, we reflect on the success of embedding immersive 3D stereo virtual reality (VR) and mobile GIS with more traditional teaching methods such as lab-based computer practicals and lectures. This is more than a technology-led mix, however; different learning spaces and aspects to a subject, and combinations of both teacher and student led work on individual and group bases are blended. Using a case study approach, focusing on GPS locational accuracy, we highlight several themes from early pilot trials for further investigation. Of particular interest are whether the spatial contingency between immersive visualisation and initial practical work is a significant factor when generalising models for blended processes in geography; whether the repetition of themes across a range of external representations and active or passive environments contributes to a cumulative learning experience; or whether the approach appears to motivate and encourage autonomous thinking by including different representations that appeal to a variety of student learning styles.

1 Introduction

This research sits within the framework of pedagogic strategies promoting spatial literacy in the teaching of GIScience. We argue that the development of spatial literacy is important both to support students from a variety of disciplines taking postgraduate courses in geographical information systems but with little geographical background, and to assist in the transfer of GIScience approaches to other disciplines less associated with geographical concepts. Initial anecdotal evidence for this has been backed up by more systematic phenomenological research, which has established that a number of students have particular difficulty in "seeing" spatial representation within mathematical or algorithmic notation. Our position differs from the of the NRC (2006) in that we pose that a lack of spatial thinking skills impinges on the development of students as GIScientists but that teaching or doing GIScience does not of itself encompass or necessarily engender the richness of "spatial literacy" as a concept. Narrowing the gap between space and place when teaching and practicing GIS is a current and important theme, but in this paper we address issues behind the ways in which we teach and students learn the basics of GI representation *as they have historically been conceptualised*.

We start therefore from a point at which it seems that some students have difficulties in internalising and manipulating spatial information from external representations delivered in a verbal and mathematical form via traditional lectures. The presentational form used may be systematic and compact, but either through a lack of familiarity with this "language", an inability to imagine multi-dimensional space that relates to learning preference, or a lack of motivation (amongst other possibilities) there arises a mismatch in mental representation between learner and that anticipated by the teacher. Baddeley & Logic's (1999) model of the working memory system, which identifies the subsystem responsible for acoustic stimuli as separate from the subsystem responsible for visual and spatial memory, goes some way to explaining the difficulty and also suggests a solution that splits cognitive load between the two "processing" systems (Mayer 2001) under certain circumstances. For example, Rapp & Kurby (2008) suggest that the use of visualisations as a particular type of external representation are particularly useful to provide a tangible expression of forms otherwise not visible to the naked eye, to highlight particularly significant elements of a scientific process or to allow students to set and test hypotheses. Using this rubric, many teaching and learning tasks within GIScience and Geography qualify for visual presentation in some form.

It is predominantly the case that immersive virtual reality applications that assist learning are reported in isolation, as unitary components (e.g. Limniou *et al.* In Press). This is important in that there is a need to know what particular impact immersion and 3D graphics have on learning processes; the approach is after all resource intensive. What is missing within this reportage are accounts that show how such visualisations are embedded within the wider curriculum. As Rapp & Kurby (2008) point out, "*careful thought must be put into the design of a complete visualisation experience, and not just the visual portion of that experience*". We know that learning accumulates; whether a particular visualisation "works" is a function (among other things) of prior knowledge and the alignment of the external visualisation with the internal representations (or learning goals) we wish the students to achieve. Further, different students will react to different forms of representation according to their predominant learning styles and an inclusive approach to learning is to use multiple external representations as we structure the learning experience. In this study we reflect on the role of immersive visualisation within a theatre setting as part of a wider blended approach to teaching and learning that also includes mobile computing practicals, field practice and lectures. While we use the term 'blended learning', we acknowledge critique of this term (e.g. Oliver & Trigwell 2005) and investigate how variation in context and approach from one element of a course builds from and into another as a process.

Case study: Positional errors from GPS receivers

The case study we present is designed to facilitate understanding of locational errors relating to global positioning systems (GPS); complex space-time phenomena of both intellectual and practical significance within the curriculum. Situated within a Geography Department, the work has been designed to run with Undergraduate Geographers, including joint Geographer/Archaeologists and Geographer/Geologists, as well as at M-Level as part of our MSc Geographical Information Science and MSc Environmental Informatics degrees.

The availability of GPS can be severely affected where objects occlude potential paths to satellites, for example in built-up areas of forests, and therefore the location accuracy provided by the signal can become exceedingly poor (Taylor *et al*. 2007). Four satellites are the minimum number required for 3D position fixing; when the number of satellites visible to a receiver drops down to 3 or less, the GPS is unable to give a position without the use of additional supporting techniques. The receiver-satellite geometry too affects the locational accuracy of GPS (Langley 1991). In the context of GIS teaching about location-based services, knowledge of these issues is intellectually important. Practically too, as we introduce mobile GIS to the curriculum, students need to become familiar handling GPS in the field and require a level of awareness that will allow them to assess the fitness for use of the locational data that they collect in association with other environmental data.

Four units are used to build students' awareness of GPS and mobile GIS, in a variety of configurations, as follows:

Unit 1: Lecture

Students are given a short (10 minutes for undergraduates, 20 minutes for postgraduates) lecture covering the basic principles of GPS, the limitations of GPS and lastly, measures of GPS locational quality.

The contribution of receiver-satellite geometry to positional errors is quantified by various Dilution of Precision (DOP) values. Among the DOP values, PDOP (Position DOP) is commonly used to assess the strength of satellites geometry in relation to positioning accuracy. Users measure distance to (at least) four satellites that transmit their positions in orbit. The user solves for position (x,y,z) and clock time t, as follows:

$$\hat{x} = (A^T A)^{-1} A^T b \qquad (1)$$

Where:

- $\hat{x}$ are the corrections to priori estimates of the four unknowns (i.e. the receiver position (x, y, z) and the receiver clock bias τ)
- The design matrix A contains the line of sight unit vectors and 1s.
- b is the difference between the measured pseudoranges and calculated ones.
- DOP values are a function of the diagonal elements of the covariance matrix (i.e. $(A^T A)^{-1}$) in a coordinate system.

And Position DOP is defined in Equation (2):

$$\text{PDOP} = \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2} \qquad (2)$$

The error in the final position is PDOP times the error in the range measurement. For example: 2m X 8 (PDOP) = 16m. Thus, the smaller the PDOP, the more accurate the position would be. As a general rule, PDOP values larger than 5 are considered poor. In general, satellites spread far apart tend to give low PDOP while those close together result in high PDOP.

The use of GPS is compromised by satellite visibility and unwanted reflections and diffractions of the signals (multipath). In the case of multipath being introduced by any of the satellites, PDOP will not provide a good error estimate. Given its additional complexity, multipath is introduced to postgraduate students (MSc GIS) but not Undergraduates.

Unit 2: 3D Stereo VR visualisation of GPS satellite visibility & its effect on PDOP

Within Leicester's virtual reality theatre, the students watch as a real-time simulation of Global Positioning Systems (GPS) satellite geometry is carried out in the virtual environment, in this case a representation of the University campus. The number of satellites visible to the receiver is modelled in real time as a user walks through the campus. As the user walks through the landscape, Position Dilution of Precision (PDOP) is displayed on the screen while the satellite geometry is visualised in both 3D and via an aerial view. The tour, and discussion, is led by a member of staff who is able to guide the students to particularly significant locations in this environment regarding GPS satellite accuracy.

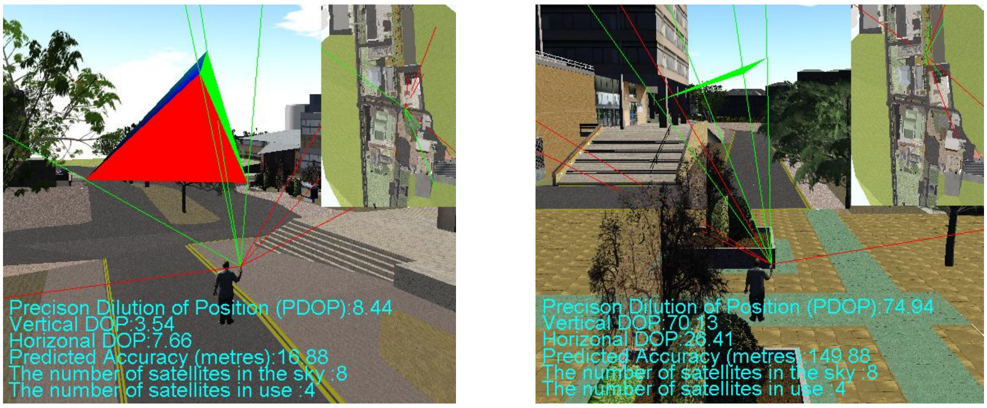

Fig. 1: Real time Virtual Reality demonstrator of GPS satellite reception and resultant PDOP showing (a) PDOP of 8.44 from four satellites and (b) Lack of accurate PDOP from four satellites owing to poor satellite geometry.
(Footprint data © Crown Copyright Ordnance Survey. All Rights Reserved)

Fig. 1 (a) & (b) are screenshots of two frames from a real-time simulation environment. Both figures show a person holding a PDA equipped with a GPS receiver standing in an urban canyon environment on campus. Green rays indicate satellites visible to the receiver, red rays point to satellites blocked by the buildings on either side of the road. The aerial view rendered on the upper right corner of screen visualises azimuth and elevation angle of the satellites. Shorter rays in the aerial view indicate satellites with higher elevation angles. The text at the bottom of the screen updates as the user moves across the campus. The 3D volume of the tetrahedron is an indication of GPS accuracy at a particular location. The larger the 3D volume of the tetrahedron, the smaller the PDOP, and hence the more accurate the position should be. The two figures clearly depict how extremely poor satellite geometry could occur in an urban environment. In practice, GPS data collected in Figure 1b is unreliable and should be discarded. For MSc students, their understanding both of PDOP and of wider theoretical issues affecting positional accuracy (such as multipath) are assessed using a written short question format.

Unit 3: Skills building practical - Using GPS-enabled Mobile GIS for point/polygon data capture across campus

Students undertake a practical exercise designed to build their mobile GIS skills using Arc Pad™. The goals of this practical are firstly to use the GPS facility within ArcPad™ to find their way to pre-selected points and identify what lies at those locations, and secondly to collate detailed data of geographical features not marked on standard Ordnance Survey 1:10,000 mapping, such as statues and flower borders. In the case of MSc students, comparisons between single receiver and differential corrected GPS signal data are made for these points of interest in the laboratory as a more advanced second element to the practical work.

Unit 4: Research skills – GPS-enabled mobile devices used as part of an overall environmental research exercise

Having provided students with an initial theoretical context and practical skills training, this unit relegates the use of GPS-enabled mobile GIS to that of a tool in the service of a wider environmental research project. Technical assistance is reduced both in terms of focus and staff skill set, although help and encouragement in the use of GPS and mobile GIS does also form part of this one day field unit.

Results & Discussion

Initial student evaluations of the mission tool and its role in the teaching about GPS accuracy have raised a number of issues for further investigation. Firstly, it does seem that the direct spatial connection between the VR visualisation of GPS accuracy and the subsequent mobile computing practical across campus provides a powerful means of altering behaviour. Prior to running the campus practical in conjunction with the VR tool as here, considerable frustrations relating to loss of signal across the enclosed campus space emerged in the student group, compromising longer term objectives relating to the embedding/enjoyment of mobile GIS within the broader curriculum. Having seen the VR tool, Student A (MSc GIS) commented regarding their behaviour during the subsequent practical that "*It's good to know where like hotspots were, because if you did say where you are, looking at his model you could see where really bad spots, now that seemed to stay in my memory because I did go straight to [good] spots that I saw…*". Blending visual (immersive virtual reality) and active learning for the *same geographical space* is a process that appears to have advantages, echoing the general findings of those using non-immersive virtual field courses to assist their students in preparing for unknown territories but in a very spatial sense (Kelly & Riggs, 2006). What we do not know at this point is whether the effect would be equally strong if GPS accuracy was presented for an alternative urban environment instead, and how the knowledge about GPS accuracies learned on campus is subsequently extrapolated to alternative field sites in detail.

Participant observation of student awareness of GPS accuracy in the research-focused field day suggests that in the main students had been enabled to evaluate the causes of signal loss (e.g. within trees) tying GPS accuracy and sample strategy together well. GIS staff were present to correct any poor practice, such as the use of GPS to locate samples within 1m of each other on a transect thus fostering the translation of concepts within a wider learning framework.

Whether the VR approach is *necessary* as an instructional method is a different question, the answer to which is likely to vary according to the ability of individual students to imagine spatial manifestations of mathematically described events. Research comparing the results of an outdoor practical exercise assessing the likely PDOP at different locations between students who viewed the VR demonstration pre or post fieldwork is underway. This work will in due course allow us to quantify the degree to which spatial manifestation of GPS accuracy in VR alters the learning behaviour in the mobile learning phase. However, to focus on the impact of the VR tool on its own in this discussion is, perhaps, to miss the point. The majority of our learners considered themselves to learn particularly well using visual materials and practical activities; all were in favour of the *combined* approach, suggesting that the blend we applied promoted engagement. Further, strong evaluative scores were received regarding the degree to which students felt they could evaluate the fitness for use of mobile digital equipment versus traditional pen and ink approaches; learner autonomy was promoted. The educational process discussed here, with its blend of teaching approaches that reinforces understanding across the three axes of learning style, impacted on student perception and motivation. On the basis of data collected to date, the use of a blend of materials not only contextualises the use of VR but also suggests that variation is actually of critical importance if its visual potential for enhancing spatial literacy is to be maximised. Over several additional student cohorts we hope to explore these ideas further and ground them on a wider evidence base.

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