

Developing Trainee Teacher Practice with Geographical Information Systems (GIS)

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There is general agreement that Geographical Information Systems (GIS) have a place within the geography classroom; they offer the potential to support geographical learning, exploring real-world problems through student-centred learning, and developing spatial thinking. Despite this, teachers often avoid engaging with GIS and research suggests that the lack of GIS training in initial teacher education is partially to blame. In response to this, this article explores how 16 trainee geography teachers were supported to develop their use of GIS across a one-year, postgraduate teacher training course in England. The project, an interpretive case study underpinned by a constructivist epistemology, used questionnaires and interviews to elicit trainees' understandings of the nature of GIS, and to explore their engagement with it across their training year. Results suggest a programme of embedded training developed in trainees a more nuanced understanding of the value of GIS for supporting geographical learning and, thereby, increased self-efficacy towards and engagement with it in their teaching practice. However, not all trainees embraced GIS as a pedagogical tool and the study raised several key issues for geography teacher education, including the knowledge culture within schools in the teacher training partnership, and the importance of trainee self-efficacy towards GIS.

Keywords: Geographical Information Systems (GIS); Initial Teacher Education (ITE); geography; spatial thinking

Introduction

Geographical Information Systems (GIS) can be described as a set of integrated software programs designed to store, analyze, and display geographical data-information (Fitzpatrick & Maguire 2000). Since its inception, it has been integrated into a small number of school geography classrooms both globally and in England, predominantly through the efforts of a minority of committed geography teachers; Bednarz (2004) argues that these individuals have worked under the assumption that GIS offers students the opportunity to explore real-world, global issues in a way that not only develops their geographical understanding (Bearman et al., 2016), but also improves their computer literacy (Collier, 2007) and provides training in the process of collecting, analysing, evaluating and presenting spatial data (Akinyemi, 2016).

Although there appears to be a need for specific research to more confidently support these assertions (Baker et al., 2015), there is a general agreement that GIS has a significant place within the geography classroom (e.g. Bednarz, 2004; Kerski et al., 2013; Bearman et al., 2016). In any case, in England the use of GIS in school geography is not something which will go away. The 2014 National Curriculum for Geography in England¹, one of only a few globally which integrates GIS (Kerski et al., 2013), states that pupils should “interpret a range of sources of geographical information, including ... using GIS to view, analyse and interpret places and data”

¹ The National Curriculum for Key Stage 3 is mandatory for all maintained schools in England. At Key Stage 3, this relates to children at the start of their secondary schooling, aged 11-14.

(DfE, 2013), and examination specifications at GCSE and A Level² refer to the use of GIS.

Despite this, geography teachers often shy away from engaging with GIS in their classrooms (Kerski et al., 2013); it can be seen as being too technically complex, too difficult to integrate into an already busy curriculum, too time-consuming to produce resources for or simply impossible to do in departments with limited access to computers (e.g. Höhnle et al., 2015). Previous research analysing why teachers have not been receptive to GIS has suggested that the lack of training in trainee and in-service teachers' professional development, alongside a lack of development of GIS pedagogy and associated resources, are to blame (e.g. Hong & Stonier, 2015; [Gatrell, 2004](#)).

Successful use of GIS in education requires that teachers have a strong understanding of geographical content knowledge, geospatial software applications, data analysis techniques, and pedagogical strategies (Coulter, 2014); as such, professional development in teacher education should be expanded to embrace the technological pedagogical content knowledge (TPACK) which captures the interplay between content, pedagogy, and technology and better supports trainee teachers to engage with GIS in their teaching practice (Bednarz, 2004; Mishra & Koehler, 2006). However, there has been relatively little research to explore how to develop initial teacher education (ITE) to do this, particularly within the context of the UK. In response to this, I undertook research to explore how a programme of GIS training, integrated within a

² GCSE examinations are sat by students at the age of 16, whilst A Level examinations are taken at the age of 18 in England.

one-year, postgraduate (PGCE³) teacher training course in England, developed trainee understandings of the value and nature of GIS and their subsequent practice with it in the geography classroom. This paper explores the findings of this research.

Literature Review

A rationale for GIS in Geography

GIS has been used within higher education (HE) contexts almost since its inception; however, its use in secondary schools did not start until the early 1990s (Kerski et al., 2013) when it began, particularly in the US, to be considered a tool which had the potential to develop students' engagement with technology (Goodchild & Kemp, 1990; Lemberg & Stoltman, 2001). Kerski et al. (2013) argue that the rapid increase in GIS use in some global secondary school contexts since then is due mainly to the perceived benefits it provides. Bednarz (2004) summarises these by outlining what she identifies as three competing yet complementary justifications for incorporating GIS into secondary school education:

Firstly, the *educative* justification that GIS enhances teaching and learning in geography, in particular through the development of spatial skills. Bearman et al. (2016) suggest that spatial thinking skills are important in geography because they help students to access and make sense of geographical (spatial) information, thereby supporting their understanding of the complexities of many contemporary global problems. It is widely proposed that spatial thinking skills can be developed with GIS (e.g. Akinyemi, 2016; Huynh 2009); it can empower students to think spatially (Lee and

³ The PGCE is a one-year higher education course in England, Wales and Northern Ireland which provides training in order to allow graduates to become teachers within maintained schools. Within it, trainee teachers spend time in both university and school settings.

Bednarz, 2009), ask spatial questions (Nellis, 1994), visualise spatial data (Marsh, Golledge & Battersby, 2007), perform spatial analysis (Bednarz & van der Schee, 2006) and, thereby, to become active learners of geography.

Secondly, Bednarz outlines what she terms the *workplace* justification, or GIS as an essential skill (2004). Many arguments for employing GIS in the classroom use workplace skills as the most important justification (e.g. Goodchild & Kemp, 1990); the inclusion of GIS in secondary education is thus given a utilitarian role in which education policy is justified to meet workplace needs by providing trained workers for the information economy. As such, Borsheim et al. (2008) suggest that teachers who apply GIS technologies do more than motivate students with the latest cool tool, they prepare students with what they call multi-literacies for the technological world.

Finally, Bednarz (2004) proposes the *place-based* justification for GIS, or the argument that it supports study of the environment of a local community. There has been significant work on place-based education within geography education research (e.g. Bednarz & Bednarz, 2003; Smith, 2002); studying the local community fits well with current education theories, particularly those related to constructivism, as well as calls for relevant education rooted in local, real-world problems. GIS allows students to work together on such problems by collecting, recording, and analyzing their own data within student-centred, locally-based geographical enquiries (e.g. Kerski, 2003).

The Problem with GIS in Schools

Despite these purported benefits of GIS, alongside the growing emphasis on GIS in the formal curriculum (DfE, 2013), there is still considerable debate as to its impact in the classroom (e.g. Akinyemi, 2016). Perhaps as a result, Kerski et al. (2013) argue that uptake of GIS in schools has been slow and inconsistent, and while the majority of

geography teachers have increasingly heard about it, they may confuse it with GPS or digital maps, thus missing the analytical capabilities of the tool.

Teachers' successful integration of technology in their classrooms has been the centre of significant academic debate both more broadly (e.g. Lee & Lee, 2014) and relating to GIS. Studies investigating teachers' use of technology often cite two main themes: those relating to resources and the structural environment, and those relating to the teachers' knowledge, skills and beliefs. Resource issues include availability and cost of relevant hardware or software (e.g. Goktas, Yildirim & Yildirim, 2008), or institutional barriers, such as time (for training, planning and [curriculum time for teaching](#)), technical support and school culture (e.g. Ertmer & Ottenbreit-Leftwich, 2010). Those issues relating to teachers include a wide range of potential difficulties (Höhnle et al., 2015); at the most obvious level, teachers' computer skills may be lacking (e.g. Ertmer, 1999), but perhaps more importantly they may lack the TPACK required to create teaching and learning activities to develop student understanding (Hong & Stonier, 2015; Akinyemi, 2016). Beyond this, there is also evidence to suggest that teachers' self-efficacy beliefs toward technology integration are a significant determining factor of their use of technology in lessons (Lee & Lee, 2014). This is supported by Blömeke et al. (2014) who argue that many teachers are characterized as being 'technophobic' about using ICT and, perhaps more importantly, those beliefs are often resistant to change. Self-efficacy describes the strength of a person's belief in their ability to complete tasks; it is situated within Bandura's (1997) social cognitive theory of human behaviour which stresses the importance of self-efficacy in the reciprocal interplay between behavioural actions, environmental factors and personal factors. Learners with high self-efficacy exhibit behaviour which has a positive impact on learning, such as showing more perseverance, viewing challenging tasks as something

to be mastered, and recovering quickly from setbacks (Pajares, 1996); as a result, learners with greater levels of self-efficacy tend to achieve at higher levels (Bandura, 1997).

GIS in Teacher Training

Bednarz suggests that among the reasons for the lack of teacher engagement with GIS in the US context “Teachers appear to be a serious component limiting diffusion of GIS” (2004, p198). Given the relative strength of critical spatial thinking and graphicacy in US geography, as compared with England, it seems safe to assume that this concern is of equal, if not greater, significance within the English context. As such, a continuing issue in GIS implementation is effective ways to prepare teachers to use it. Despite this, there is little research evidenced to suggest explicitly how *trainee* geography teachers might be supported in developing their practice with GIS, particularly in the English context. Subject associations within England promote the benefits of GIS, but often without much in the way of support for teachers; for example, on its website the Geographical Association states “As geography teacher educators, we are all agreed that GIS is an important if not essential area to embrace in initial geography teacher education. However, knowing how to tackle it is less certain” (GA, 2011).

More broadly, there has been research examining successful and sustainable integration of generic technologies into trainee teacher practice. In particular, studies suggest structural support for trainees is significant; this includes not only time for training within the programme of study (Hattie, 2009), but also the establishment of professional learning communities within which ITE institutes and schools work collaboratively toward supporting trainees (Lipowsky, 2013; Lee & Lee, 2014). In addition, pedagogic features of successful integration of technology into trainee practice

are significant; in particular, the foregrounding of TPACK, rather than a focus on technology-related skills (Hong & Stonier, 2015), and embedding opportunities for trainees to trial new ideas and reflect critically on them. Successful ITE programmes support trainees to reflect on their developing technological competence and self-efficacy towards it (e.g. Höhnle et al., 2015), as well as including opportunities for co-creation of training activities with peers and peer feedback on teaching (Putnam & Borko, 2000).

This study explores trainee geography teachers' understandings of GIS in an attempt to identify factors influencing their decisions about using GIS, and to consider how they can be supported in developing their practice with it. As such, it addresses the following research questions:

1. What are trainee teachers' understandings of the nature and value of GIS at the beginning of their training?
2. How and by what processes do these develop over the course of the year?
3. How can trainee teachers best be supported in developing their use of GIS?

Context and methodology for the research

Context of the study

The research was undertaken with one cohort of Secondary Geography PGCE trainees within a university in England. This PGCE course develops trainees' geographical content knowledge (CK) and pedagogical knowledge about the processes and practices of teaching and learning (PK) alongside their geographical pedagogical content knowledge (PCK: Shulman, 1986). For a number of years trainees have been introduced to desk-based GIS software through a practitioner-led, university-based classroom workshop, but this has almost without exception failed to lead to incorporation of GIS

into their teaching practice. During the period of research there were 16 trainees in the cohort, seven male and nine female.

Training Programme

Across the year, trainees worked with ArcGIS Online which was fully integrated into their PGCE programme of study (Table 1). [Figure 1 shows examples of trainee work from the September \(1a: a cross section of the subduction zone in Chile\) and March \(1b: hot spot analysis of crime data in Cambridge\) training sessions.](#) ArcGIS Online is a cloud-based GIS platform that allows teachers to create, view, interrogate and display spatial data very easily (Walshe, 2016). Building on the desktop version of ArcGIS, much of the functionality of ArcGIS Online can be used free of charge by creating an individual user account; as such, it presented us with the opportunity to avoid issues of potentially problematic and expensive installation of software into school IT suites, and offered trainees the opportunity to work with GIS in a range of settings ([Jo, Hong & Verma, 2016](#)). ESRI⁴ provided full licenses for partnership schools across the year.

[PUT FIGURE 1 HERE](#)

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Methodology and methods

This project was framed as an interpretive, multiple methods case study underpinned by a constructivist epistemology in recognition of the social construction of trainee understandings of the nature of GIS and individual engagement with it (Crotty, 2005). A

⁴ ESRI (Environmental Systems Research Institute) is an international supplier of geographic information system (GIS) software, web GIS and geodatabase management applications, and the owner of ArcGIS Online.

number of research methods were undertaken to explore trainees' developing understanding of and engagement with GIS.

Questionnaires

Across the PGCE year, seven questionnaires, comprising mainly open questions, were undertaken to explore trainee understandings of the nature and value of GIS, their use of GIS in schools, and, where relevant, their reaction to any training event they had experienced.

Interviews

Interviews were undertaken with trainees twice: once at the start and once at the end of the year. I used individual, semi-structured interviews comprising both direct questioning and discussion following unprompted comments (e.g. Longhurst, 2010). In both interviews, trainees were asked to define GIS and consider its value for geographical learning, as well as to reflect on their own confidence with it. In the initial interviews, trainees were also asked to describe any prior experiences with GIS; in the final interviews they reflected on how they had used GIS within their teaching practice, what had best supported them and what the most significant 'blockers' had been.

Data analysis

Analysis of questionnaire and interview data was achieved through open, manual coding combining a thematic and case-based approach to the data, attempting to balance breadth and depth of focus (after Dey, 1993). Through this process a set of classification categories emerging from the data (inductive content analysis) was used to follow through strands in learning across it; this was an iterative process undertaken a number of times to increase validity of the coding and blind as to both the identity of the trainee

and timing of the data.

Findings and Discussion

This section firstly considers how trainee understandings of the nature and value of GIS developed across the year, drawing on interview and questionnaire data to address research questions 1 and 2 and using vignettes of Krissie and Charles to exemplify trainee responses to the training programme. It then moves on to explore research question 3, taking a thematic approach to a discussion of the implications for geography teacher education.

What are trainee teachers' understandings of the nature and value of GIS at the beginning of their training year? How and by what processes do these develop over the course of the year?

PUT FIGURE ~~1~~2 HERE

Across the year, trainee definitions became richer and more nuanced in their understanding of the breadth and depth of GIS ([Figure 2](#)). Initially there was a combined frequency of 46 mentions, the majority of which related to the idea that GIS is a map (12 mentions) or a way of visually displaying data (11 mentions). For example, Molly defined GIS as “a method for mapping spatial data”, and Ray “how science geographers use mapping.” At the end of the year, the combined frequency of mentions had risen to 91, and whilst the majority included reference to GIS as being a “way of visually mapping data” (Amanda), many also began to consider the wider scope of GIS to support geographical thinking; for example, Molly’s June definition described GIS as “a computer-based software that allows you to collect, store, process, display, analyse geospatial data”.

PUT FIGURE ~~2~~3 HERE

Increased recognition of the scope of GIS for supporting geographical learning also emerged from trainee interview responses (Figure ~~23~~3). In September, trainees struggled to identify how GIS could support learning, many arguing that it is simply a novel pedagogy; in this way, trainees were drawing on the ‘novelty value’ of using technology, rather than seeing it as a pedagogical tool to support learning. For example, Ray comments “It's good to show that geography has an IT side to it rather than just sitting down learning, it gives a bit more of an exciting element to the course”. However, at the end of the year, the majority of trainees identified the potential of GIS for supporting learning as being able to visualise geospatial data; for example, Josh suggests it provides a platform to “see [the] data alive”. Beyond this, many also considered the use of GIS to support higher level geographical thinking; for example, Brian states “it enables one to get data presented and the more boring parts of analysis done very quickly, so you can focus on higher order geographical analysis”. Perhaps interestingly, few trainees were able to verbalise the ‘higher level geographical thinking’ GIS supported; some talked about synthesis of information, application of data to real world problems, or use of visual representations to support predictions, but few exemplified beyond this. This suggests that trainees would benefit from a more metacognitive approach to learning GIS that makes the content knowledge (CK) of spatial thinking and how GIS can support this explicit (as suggested by Acheson & Bednarz, 2003).

Trainee confidence with and self-efficacy towards GIS

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Only one student had not used GIS before in any context. Of the remaining 15, the majority (11) had used it within their undergraduate degree and one at school; three had not used it within an educational setting, but recognised that they did so in 'everyday' contexts, for example "Google maps on my computer" (Charles) or "Everyday life like GPS" (Tristan). Within the university context, GIS was predominantly incorporated into one module across the undergraduate degree, although experience varied within this considerably.

Trainee confidence with using GIS in September was low with 11 saying they were 'not at all' confident (Figure 34). Many trainees reflected on the lack of learning from their undergraduate experiences; for example, Sophie commented

"I think it was quite daunting because every session was just a new sheet, a new river of information and a new task. I don't know how much I learnt from it because I was just following the steps on the sheet and putting them into the computer."

This was echoed by Brian who commented

"It was one of those things you did at the start of the year, you jumped through the hoops, you had problems you asked the coordinator and then you sort of tick the box 'Thank god I've done that' and then you moved on."

This reflects Bearman et al.'s (2016) findings that GIS in HE is often taught in a specific skills-based module with a cook book style of pedagogy, rather than being embedded across the curriculum. MaKinster, Trautmann and Barnett (2014) suggest that this approach to GIS training does little either to engage students with the technology or support them in learning how to use it; instead, it alienates students and limit its perceived relevance as they see it as a box to be ticked, rather than an integral part of the geographical toolkit.

In June, only one trainee said they were 'not at all' confident with using GIS, the majority (10) suggesting that they were 'quite confident'. Many trainees identified aspects of GIS that they felt more comfortable with; for example, Lois commented

“Very confident with the basics and fairly confident that when I want to do more complicated things I have the know-how to find out how to do them”. Story maps were most frequently referenced as something trainees felt confident with creating; for example, Tristan suggests “I could definitely make a story map from scratch ... and design a lesson around that.” Many trainees commented that the use of web-based GIS provided them with a much simpler interface than desktop versions they had previously worked with, thereby allowing them to devote their time to teaching and learning, rather than grappling with the technical functionality of the software (as suggested by Jo, Hong and Verma, 2016). However, despite this, One commonly stated reason for the persistence of a lack of confidence at the end of the year persisted as was that of technical issues relating more widely to computer use (rather than to specific GIS functionality); for example, Lucinda explained “I'd say I'm not very confident in letting the pupils use it themselves, because any technical problems they would come across I would probably struggle to fix”. This reflects a concern found by Hong and Stonier (2015) among in-service teachers about the reliability of the technology, but also again illustrates the impact of their self-efficacy towards technology as an important factor inhibiting its subsequent take-up within the classroom (Lee & Lee, 2014).

The next section provides vignettes of two trainees with different experiences with GIS over the year, with the aim of informing discussion about the GIS training programme as a whole.

Krissie

Krissie joined the PGCE course having completed a PhD in Archaeology during which time she gained a range of experience with GIS, particularly QGIS. As such, she understood the power of GIS for analysing geospatial data, but was also very much aware of its challenges. In her September questionnaire she already showed a relatively

broad understanding of GIS as “a way of organising databases of information relating to the environment and [aiding] interpretation and understanding”. Perhaps as a result of her previous positive experience with GIS, Krissie engaged quickly and effectively with it in her teaching practice; she developed a rapid understanding of its functionality at the beginning of the PGCE and spent the rest of the year exploring the TPACK required to develop her students’ geographical learning. By Christmas she had designed a geographical enquiry sequence exploring school microclimate; as such, she was already developing GIS as a way of supporting student-centred, enquiry-based education with a local focus, as suggested by Kerski (2003) and Bednarz (2004). [An example of a story map produced by Krissie which describes how she developed her use of ArcGIS online can be accessed online here.](#)

Across the rest of the PGCE year, Krissie continued to employ GIS both as a way of visualising geospatial data for whole-class discussion, and engaging students in data analysis and interpretation tasks themselves. She became an advocate for GIS, giving presentations to PGCE trainees from other disciplines, supporting practical workshops for in-service teachers at the ESRI Conference and leading the training for the biologists in June. In her final interview, Krissie clearly articulated her belief that GIS should be used within geography classrooms:

“[It is] really useful for a whole range of tasks from something where it's just a very quick introductory starter through to a whole sequence of lessons where it's part of a problem-based learning exercise. [GIS] moves forward students' understanding of topics in geography and also their skills.”

When considering why she engaged so successfully with GIS, Krissie suggested that her previous experience meant that she was not scared of it, but knew its potential for supporting enquiry-based learning using geospatial data. This finding is echoed across the group as those trainees who had more positive experiences of GIS at undergraduate

level (so had stronger self-efficacy towards it) engaged far more frequently and effectively with GIS across the PGCE.

Charles

Charles joined the PGCE as a mature student with a PhD in geopolitics, but no prior experience of GIS in education. In September, he produced a very detailed definition of GIS and its applications:

“digitising, summarising or simplifying features of the world to assist planning, inform policy and educate. The data it works with is spatial and is used to explore human and physical aspects of the environment...analysis could take place at any number of scales; it could be the globe, the city, a neighbourhood, perhaps even a back garden or comparing people’s back gardens”

However, he does not feel comfortable with what he perceives to be the underlying positivist theoretical perspective of GIS, asserting “it doesn’t see the world in a way that I want to see the world”. Johnston (1997) argues that being an academic geographer involves being socialised into one of the disciplinary traditions that co-exist within it, and that many academic geographers adopt a particular epistemological position and remain within that for a long time. For Charles, his epistemological standpoint initially inhibited his engagement with GIS; the perceived disconnect between GIS and his preferred epistemological viewpoint unsettled him, giving him low self-efficacy towards it. At the same time, Charles was also struggling with the practical demands of the PGCE course; the depth with which he reflected on the disciplinary component of his lessons was among the most intense I have seen, and he developed an impressive range of geographical PCK (Mishra and Koehler, 2006) to support this. However, he struggled with managing his time for such detailed lesson planning and was, as a result, left with little time (or perhaps inclination) to develop the TPACK necessary to support his practice with GIS. Charles verbalises this in his final interview:

“I do think [GIS is] important but from my perspective as a trainee teacher ... given all the other pressures that trainees are under and the priorities they have for their training, I've not actually

considered it a high priority at all. As a result my default position has been to pretend that it never happened.”

As a result, Charles did not engage with GIS in school across the year beyond the use of one 3D OS map to illustrate a glaciated landscape. However, with time to reflect on this in his final questionnaire he appears to regret this: “I really do wish I had engaged with GIS this year but for whatever reason – accumulated exhaustion perhaps – I didn’t manage to”. He considers his understanding of GIS in his questionnaire entry commenting

“Before I saw GIS as a quite closed, limited way of viewing the world (a bunch of quantitative ‘stuff’ or stats) but now I can see there is a lot of creative potential for understanding (as well as teaching) geography..... it’s a very neat way of exploring the complexity of places too”.

In this way he is starting to recognise the potential of GIS for his future practice;

Charles explores the reason for this, commenting “it was useful to hear from my fellow trainees about their varied experiences of using ArcGIS”. As such, the catalyst for this change in perception of the value of GIS appears to be the dissemination session in which he heard practical examples of how his peers had successfully used GIS.

How can trainee teachers best be supported in developing their use of GIS within their training year?

Several themes emerged relating to how trainees can best be supported with developing their use of GIS across their PGCE:

The importance of ‘knowledge’

In the US context, Bednarz (2004) argues that one of the most significant issues affecting whether GIS has a positive effect on student spatial thinking in the classroom is *teaching for understanding*, or teaching so students gain usable knowledge connected and organised around key concepts. It makes sense to expect trainee teachers to develop their geographical PCK and TPACK across their PGCE year (Mishra & Koehler, 2006);

however, beyond this, the findings of this study agree with Mitchell and Lambert's (2015) assertion that learning to teach a school subject requires time for trainees to continue to develop their subject disciplinary knowledge (Schulman's content knowledge, CK: 1986). Across the year this emerged as a challenge for some trainees as they grappled with multiple strands of learning, considering not only TPACK but also establishing the CK required in the classroom. This was worse for trainees who saw GIS as peripheral to the 'nuts and bolts' of geographical teaching and learning. For this reason, geography teacher educators cannot assume that simply by *doing* GIS, trainee teachers will recognise or learn critical spatial thinking. Instead, they need to develop approaches to teaching GIS that make the 'powerful' knowledge (Young, 2008), that worthwhile and meaningful disciplinary knowledge relating specifically to geospatial thinking, explicit; they must then give trainees sufficient time to develop this, alongside their GIS TPACK.

The balance between application and transferability

Beyond the knowledge, this study highlighted the importance for trainees of practical, relevant examples of how GIS can be used to support learning in the classroom. For example, when considering what training was useful Charles stated "[making] us aware of different applications of GIS in schools"; whilst Krissie reiterated the importance of showing "the relevance and utility of the technology". The most highly rated training activity was the workshop led by a practicing geography teacher which explicitly showed how GIS could be used to support geographical thinking through specific learning objectives. However, despite the importance of practical examples, Bednarz (2004) argues that the ability to extend what is learned in one context to other contexts, or *transfer* (after Byrnes, 2001), is also significant. She proposes that the relationship between learning and transfer is seminal; if students learn

by following sets of procedures in specific contexts they can fail to transfer flexibly to new contexts. This is particularly important within the context of web-based GIS applications, such as ArcGIS Online, which are by their very nature more frequently 'upgraded' to develop their functionality and ease of use in response to advancements in technology. Within this study, those trainees with less confidence requested step-by-step guides to support them, and Amanda reflected on the December training session stating “It was really useful ... but I still feel like I would struggle to create things which were not almost identical to those done in Faculty”. This again draws attention to the risks of ‘clickology’ or cookbook-style approaches where learners become reliant on instructions and fail to develop higher level skills required to transfer knowledge to other contexts (MaKinster, Trautmann & Barnett, 2014). In this way, an interesting dichotomy arises; ITE programmes need a balance between training which provides clear examples of how GIS can be used in the classroom on the one hand, and instruction that requires trainees to learn at a higher, more abstract level in order to support learning for understanding and transfer (Bednarz, 2004) on the other.

The role of schools in the teacher training partnership

However strong the support and training for GIS at university, for trainee teachers much of their time will be spent in schools; as such, the role of schools emerged as one of the most significant factors affecting trainee engagement with GIS. Despite the consensus that the use of web-based GIS has made it significantly more accessible than its desk-based counterparts (Jo, Hong and Verma, 2016), At its simplest, the physical environment in the form of computer access and wifi reliability persisted to be a problem within some schools. 13 of the trainees identified these as significant issues impeding their use of GIS; for example, Lucinda commented “Technology [is] the greatest barrier”. In this way, trainee references to the technical issues associated with

GIS implementation in schools are replete with references to computers as what Meskill et al. (2002) refer to as the locus of agency in the instructional process. In some cases, issues of technology also impacted the acceptance of GIS by school students being taught by the trainees; for example, Krissie commented “I found year eight were quite resistant to it. There was a scepticism that the software and the hardware was actually going to function ... they weren't prepared to trust [it].” In this way, previous negative experience with school technology by *school* students meant they were more reluctant to work with GIS in their geography lessons, thereby providing an additional level of difficulty for the trainees.

Beyond the technology, school or departmental culture towards GIS played a significant role in trainee engagement with GIS, as found by Ertmer and Ottenbreit-Leftwich (2010). For example, Cath commented

“it wasn't encouraged, it wasn't on the radar of the school, so it wasn't being pushed from the school's point of view....I never saw them use ICT rooms, it was only me, I never ever saw the geography teachers using IT”

Here Cath refers not only to a lack of structural and verbal support by school mentors, but also a lack of modelling by geography teachers she observes as part of her training; as such, there is a disconnect between what she is being taught at university and the practice she is observing in school (Ottenbreit-Leftwich et al., 2010). There are, perhaps, two ways to overcome this: the first is to develop modelling using GIS within the university setting (Tondeur et al., 2012) – if university tutors teach *with* rather than just *about* GIS this might support trainees to develop a more critical understanding of GIS pedagogies. The second, perhaps more challenging but ultimately more effective, is to support school mentors to develop their understanding of and practice with GIS. Within this study, mentors were given two training sessions within mentor meetings, as well as documentation to support trainees in school; however, the most impactful event

was mentor training *alongside* trainees at the November training weekend. Through this, mentors and trainees were able to work together to develop a range of lesson plans and resources for specific classes. As such, they began to forge a collaborative relationship which the trainees reported extended beyond the context of the training course.

One final way that school mentors inhibited trainee practice with GIS was through management and assessment of trainees within lessons. For example, Brian recalled “if something takes a couple of minutes to load and students become a bit restless behind you that's a chaotic start to the lesson straight on the lesson observation”. Although Brian here is referring to technological challenges, it is the reaction to these by his mentor that is more significant; the culture of high performativity within schools in England and subsequently on trainee teachers as performers rather than learners (Beauchamp, 2015), means that Brian is not being encouraged to risk-take within his lessons. Where manifested in the relationship between mentor and trainee, this has a constraining rather than progressive influence on the trainee who subsequently is likely to avoid pedagogies which they see as potentially carrying more risk (such as GIS). In this way, it is important that PGCE courses create a culture of creativity and risk to develop trainee classroom practice that is supported not only in the university context, but also in schools.

Trainee teachers' self-efficacy: an underpinning factor

At the end of the year, nine of the 16 trainees stated that one of the most significant ‘blockers’ that was still stopping them from developing their practice with GIS was their own confidence. For example, Vihini commented “I don't have the knowledge and confidence, or the technical ability”. Pajares (1996) suggests that people with low self-

efficacy may believe that things are tougher than they really are which subsequently fosters stress; perhaps as a result, those trainees who most strongly stated their lack of confidence with GIS were unsurprisingly those that engaged least with it in their classroom. However, for some trainees, their self-efficacy developed across the year, even when tested by the students they were teaching. For example, Amanda reported:

“when the kids are going 'Oh Miss, can you just give it to me on a piece of paper?’ you think 'Oh no, I'm teaching this wrong because they're being quite resistant, rather than thinking no, this is a different approach to learning, this isn't being spoonfed, this is they're really having to think for themselves and they will get there and they'll get something better, but I have to kind of hold my nerve and get them there.”

As such, a trainee teacher's self-efficacy beliefs towards integration of GIS appeared to be a significant determining factor of their engagement with it in their teaching practice, echoing the findings of Abbitt (2011); where trainees such as Amanda persevered through challenges and began to see the benefits of GIS to their students' learning, their confidence and practice with it developed as a result. At interview, trainees identified opportunities to disseminate practice as developing their confidence with GIS; as such, these could be introduced earlier not only to showcase trainees' work but to provide time to develop a culture of collaboration and reflective dialogue among a community of learners (Lipowsky, 2013) which could then support trainees as they went back into schools.

Conclusions

This study explores trainee geography teachers' responses to a GIS training programme across their PGCE year, considering how they engaged with it, and drawing out tentative implications for ITE. Trainee understandings of the nature of GIS became more nuanced across the year, from seeing it as a method of data display to recognising its value for supporting student-centred, enquiry-based learning and the development of

geospatial thinking. It was generally agreed by the trainees that the gradual yet repeated exposure to GIS with increasing complexity across the year supported the development of their practice as it gave them the opportunity to engage with it at their own pace, allowing them to ‘try out’ ideas from training sessions in school and come back to university to share ideas with their peers at regular intervals. As a result, a number of trainees engaged effectively with GIS across the year, integrating it into their practice to enhance geographical learning within their classroom; these very quickly ‘learnt’ the relatively simple functionality of the web-based technology, and soon came to view it as a means rather than an end to learning (Meskill et al., 2002). Although access to technology was not always straightforward, their underlying belief that GIS was beneficial for student learning meant that they persisted through any difficulties faced, and in doing so their self-efficacy towards it steadily developed. This supports Bandura’s theory (1997) that self-efficacy beliefs play a mediational role in relation to cognitive engagement by influencing effort, persistence, and perseverance; trainees with higher self-efficacy towards something use more cognitive and metacognitive strategies and persist longer than those who do not (Pajares, 1996). According to Bandura (1986) enactive attainment, or the experience of success, is the most influential source of self-efficacy; social cognitive theory suggests effort should, therefore, be made within ITE to develop pedagogies which raise trainee competence in and *confidence with* GIS, such as through successful, authentic mastery experiences (Pajares, 1996); with greater self-efficacy towards GIS trainees would more actively engage with it, overcoming potential challenges, such as technology issues, to develop it as an effective pedagogy with which to support geographical learning.

However, despite the development in the majority of trainees’ understanding of the value of GIS, many failed to engage significantly with GIS in their classroom

practice across the year, using it predominantly (and rarely) as a vehicle through which to collate and display geospatial data. It is perhaps surprising that a generation of 'digital natives' (Prensky, 2001) did not better embrace the challenges of what for most of them was a relatively new technology. There appear to be a number of reasons why this is the case, the first being the legacy left by experience of GIS at undergraduate level. For many, GIS at university was undertaken within a discrete, skills-based course which limited higher level engagement with and transferability of understanding, and more often than not left trainees with a limited view of the relevance and practicality of GIS to geography (as suggested by Lloyd, 2001). As such, undergraduate experience with GIS appears to impact both trainee attitudes and self-efficacy towards it which in turn affect their engagement with it in their teacher training year. In this way, undergraduate use of GIS has a significant role to play in determining the extent to which trainees engage with it.

A second reason frequently cited by the trainees as restricting their engagement with GIS is the limitations of technology; however, I suggest this can sometimes be a 'perceived' factor, frequently perpetuated by mentors in school who do not have the desire to engage with GIS themselves, and used by some as a reason not to commit time to it. Within the context of the PGCE, this highlights a significant challenge with developing trainee practice with what is still seen by some as a new (and often unmanageable) technology in schools: the split of trainee practice between university and school. Many of the 'blockers' to trainee engagement with GIS were related to schools, be they technology systems, departmental cultures or mentor experience or opinions. Although this is not a new issue for teacher educators within ITE, it perhaps becomes more obvious when supporting trainee teachers with developing practice with new technologies, such as GIS. But what does this say about learning cultures within

schools hosting trainee teachers? The majority of geography departments have yet to incorporate GIS which means that expertise with it has the potential to provide trainees with their own 'niche', knowledge they have to offer host schools. However, despite mentor rhetoric that they value PGCE trainee expertise, this does not always appear to play out in practice where instead trainees can become disempowered by departmental culture or individual mentor attitudes. Where departments are reluctant to engage with GIS, the lack of trainee self-efficacy can mean trainees conform to the culture of the school, rather than arguing the case for GIS themselves. Where mentors themselves lack confidence they may be uncomfortable with a trainee being more knowledgeable about GIS than themselves; in this situation, they may devalue or discourage the use of GIS to ensure the power dynamic remains in favour of them, rather than the trainee. This may be worse within the context of a PGCE where the perceived role of mentors as assessors can generate tension in the mentor–trainee relationship. As such, the culture of knowledge within placement schools is significant in trainee engagement with GIS; a culture which values trainee knowledge has the potential to empower trainees as 'experts' to not only develop their own practice, but also to lead development of departmental practice. For this reason, it is absolutely vital to engage school mentors and departments with GIS alongside the trainees, and doing so alongside trainees at joint training and planning sessions seems to be particularly effective. In fact perhaps during a time of reduced budgets for training in schools ITE courses, particularly within the context of PGCEs, could play an important role in supporting in-service teachers with developing their pedagogy with GIS. I suggest that GIS education research now needs to focus on better understanding the relationships between mentors and trainees within schools and how these may be supporting, or constraining, trainee teacher engagement with GIS. It should then explore how these relationships can more

effectively be used to support more embedded and sustainable practice with GIS in geography classrooms for both trainees and in-service teachers. However, ~~m~~More research is also needed to consider GIS teacher training models for different ITE routes, particularly school-based routes where university input is much reduced, something which is increasingly significant within the England ITE context and where quality of provision can be variable (Foster, 2002). Will such programmes have access to PCK and TPACK training which can be supported within university contexts if they only have one or two geography trainees? Finally, I suggest meaningful incorporation of GIS into the geography curriculum should ideally begin at primary school level and web-based GIS seems to provide the opportunity to do this; as such, how might this be developed within a sector already struggling to find geography subject specialists, and what are the implications for primary ITE? Although the challenges of integrating GIS into the school geography curriculum remain significant, if we as a geographical community believe in its benefit for our students' learning, geography teacher educators must continue to work to develop strategies to support trainee and in-service teachers with it alongside their general teaching practice.

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