Real-world geographers and geography students using GIS: relevance, everyday applications and the development of geographical knowledge

While Geographical information systems (GIS) are increasingly being seen in school geography classrooms, there remains significant reluctance among teachers to engage with the technology (e.g. Hong, 2017), as well as limited consideration of students' perspectives on GIS. In response to this, we have undertaken research to explore how a programme of GIS training, integrated within a two-year A-Level examination course, develops students' perceptions of the value and nature of GIS, their subsequent engagement with it, and its impact on their geographical knowledge. This paper reports on one strand of the longitudinal research which focuses on how tapping into the expertise of real-world, industry experts can affect students' perceptions of the relevance of GIS to geography and support their acquisition of geographical knowledge. The project, an interpretive case study, used questionnaires, interviews and analysis of students' work to elicit students' developing perceptions of and engagement with GIS, as well as changes in their geographical knowledge. Results suggest that engagement with industry experts aids students' understanding of what GIS is, allowing them to develop a more nuanced appreciation of its real-world applications; this then appears to play both a direct and indirect role in the subsequent development of students' geographical knowledge.

Introduction

The value of GIS in geography education has been well established (Bednarz, 2004), with GIS being used successfully in "promoting spatial literacy; supplementing fieldwork and in enhancing pupils' visualisations of geographical phenomena in increasingly interactive digital environments often through geographical enquiry" (Fargher, 2017a, p.151). While GIS is increasingly being seen in school geography classrooms (Bednarz, 2004), there remains significant reluctance among teachers to engage with the technology (Hong, 2017; Walshe, 2017), as well as relatively little evidence to consider students' responses to it. In answer to this, we are undertaking longitudinal research to explore how a programme of GIS training, integrated within a two-year A-Level examination course, develops students' perceptions of the value and nature of GIS, their subsequent engagement with it, and its impact on their geographical knowledge. This paper reports upon one strand of the research which focuses on how real-world, industry experts can engage with students. This has partly been achieved through the development of relationships with industry experts in the local context, as well as through the GeoMentors network which has been newly set up by ESRI UK and the Royal Geographical Society (with IBG) in the UK but is well established in the US (Bednarz, 2016). Further reflection on the value of these relationships seems pertinent given recent acknowledgement that partnerships between industry and education could be significant in realising the full potential of GIS within the geography classroom (Kerski, Demirci & Milson, 2013).

Based on initial project findings of students' perceptions of the value and nature of GIS, it is apparent that they do not fully grasp the significance of GIS to them, their A-level studies, or to geography more broadly (Healy & Walshe, 2019). Kember, Ho & Hong (2008) suggest that establishing the relevance of a particular topic or concept is

extremely important in motivating student learning; they argue that relevance could be established through showing how something can be applied in practice, establishing relevance to local cases and relating material to everyday applications. This informed the rationale for developing the strand of research explored within this paper which explicitly examines the use of industry experts to provide avenues for students to see the relevance of GIS to both themselves, and more broadly to geography.

Literature review

The school curriculum and student engagement with GIS

The 2014 National Curriculum for Geography in England, 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" (DfE, 2013, p. 3), and examination specifications refer explicitly to the use of GIS. As such, the curriculum context within the UK provides a clear imperative for teachers to engage with GIS (Fargher, 2017b). Logistical and technological barriers to using GIS with students are well acknowledged (e.g. Hong & Stonier, 2015) and although such barriers have been diminishing in recent years (Fargher, 2017a) it is still perceived that teachers are hesitant to engage with GIS (Hong, 2017; Walshe, 2017). Walshe (2018) posits an alternative barrier, suggesting that teachers trying to overcome difficulties associated with technology may be detracting from, rather than enhancing, geographical learning; further consideration for how GIS can yield greater capacity for geographical thinking in students is needed to overcome this. Previous studies have argued that the use of GIS has a positive impact on school students' attitudes and learning, for example by increasing subject relevance (West, 2003), student self-efficacy (Baker & White, 2003), and spatial skills (Jo, Hong

& Verma, 2016); however, this research has generally involved relatively short-term, quantitative studies, predominantly within the US, and has done comparatively little to explore in more depth how and why this might be the case.

Approaches to GIS and the development of geographical knowledge

There exists two main strands of research referring to pedagogical approaches to GIS, both predominantly relating to the US context: the first focuses on spatial literacy (Kerski, 2003; Bednarz & van der Schee, 2006), and the latter on enquiry-based learning (Fargher, 2017b). However, there has been relatively little reported as to how we might measure their impact on students. One exception is described by Linn, Kerski & Wither (2005) within which geography and science teachers from Colorado developed a quantitative evaluation tool for GIS to assess: "the questions students pose, the information they gather, the way they organise the data, how they come to their conclusions or solutions, and how they present their results" (Linn et al., 2005, p. 61). The development of such a rubric seems to fit with the steps of enquiry learning with GIS as advocated by ESRI (2003); however, Walshe (2018) warns of the danger of GIS being reduced to "a mechanism for completing a set of skills" (p. 48) in the context of geographical enquiry, instead drawing on Maude's typology (2018, see Figure 1) to highlight the capacity for GIS to contribute to developing students' powerful geographical knowledge. The notion of powerful knowledge is based upon the entitlement for young people to be given access to 'powerful knowledge' that is derived from the disciplines (Young, 2008); this has been further developed in the context of geography education by the GeoCapabilities project (Lambert, 2016) and Maude (2018). For example, GIS might allow students to engage with Type 3 knowledge through the opportunities to create, test and evaluate knowledge (Walshe, 2018).

INSERT FIGURE 1 HERE

Maude's typology has also been used by Fargher (2018) to exemplify how a curriculum artefact, defined as "the 'key' to a series of lessons a given topic" (p, 8) can be created in ArcGIS Online to construct powerful geographical knowledge about 2004 Indian Ocean Earthquake and Tsunami. Such an example demonstrates the need for teachers to lead with their expert subject knowledge to ensure engagement with GIS is underpinned by the subject's key concepts and supports the development of students' geographical thinking.

Real-world experts and geography education

The significance of partnerships between industry experts and education to allow GIS to be embedded within geography classrooms has already been acknowledged (Fargher & Rayner, 2012). Kerski et al. (2013) further emphasise the role of a range of stakeholders, such as regional teacher associations, professional geographers and initiatives of the GIS industry, in providing opportunities for using GIS in education. There has been some debate as to how this might work; for example, Strachan and Mitchell (2014) propose that professional GIS experts could provide sustained technical support and use their GIS knowledge to mentor classes, whilst Liu et al. (2012) go so far as to suggest that GIS experts could play a joint role in developing GIS-based curriculum resources and data sets to allow early adoption of GIS by teachers. In order to better embed GIS into school curricula, Liu et al. (2012), speaking from the context of Singapore, also consider the need for geographical data to be available for use in

schools, especially at local scales. Real world experts working in the local context would be able to help students use geographical data from the locality to support such an enquiry-based approach. Partnerships with industry experts have previously been drawn upon to develop students' GIS skills and understanding of how GIS can be applied in the real-world; for example, geography students were teamed up with industry experts in Australia to develop the Tasmanian Arboretum's GIS inventory by installing survey reference points (Kinniburgh, 2012). However, these partnerships need to be fully explored to consider how learning is supported through such interaction with experts.

Examination of the literature then suggests that partnership between classrooms and real-world GIS experts has significant potential both to engage students with geography, as well as to make clearer its relevance to their lives (e.g. Kerski et al., 2013). However, there remains a need to understand if such engagement can support students' geographical learning. In response, this study addresses the following research questions:

(1) How might using real-world experts affect students' perceptions of the relevance of GIS to geography?

(2) To what extent does the use of real-world experts in GIS teaching support students' acquisition of geographical knowledge?

Context and methodology for the research

This longitudinal project is part of a larger study exploring how a programme of GIS training, integrated within a two-year A Level examination course, develops students' perceptions of the value and nature of GIS, their subsequent engagement with it, and its

impact on their substantive geographical knowledge. The study is framed as an interpretive, multiple methods case study underpinned by a social constructivist epistemology in recognition of the social construction of student understandings of the nature of GIS and individual engagement with it (Crotty, 2005).

Context of the study

This research was undertaken at a fully comprehensive 11–18 academy in England consisting of 1790 students. The school serves a relatively affluent rural area; few students are from ethnic minority groups or speak English as an additional language, and the number of students with special educational needs is in line with the national average (OFSTED, 2013). A class of sixteen 16- and 17-year old students were used for the case within this research, although one declined to take part in the study; the students had all opted to take Geography at A (Advanced) Level. The Geography Department had selected to follow the AQA specification (AQA, 2016); research for this phase of the study took place between September 2017and March 2018, during which time students completed the Changing places, Hazards and Coastal systems and landscapes units of work.

GIS Programme

Across the year, students were introduced to GIS using a range of approaches to working with real-world geographers (see Table 1 for full details). Practical work used ArcGIS Online, a Web-GIS platform that allows students to create, view, interrogate and display spatial data very easily. ESRI[1] provide full licenses for schools which offers

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

students the opportunity to use GIS in a range of settings (Jo et al., 2016). Figure 2 shows examples of student work from the fieldwork enquiry exploring whether there is a positive place attachment to Mill Road in Cambridge. Real-world geographers presented on GIS use in real-world situations including protecting and promoting river environments in the UK, and exploring products used to aid decision making by governments and NGOs following natural disasters.

INSERT TABLE 1 HERE

INSERT FIGURE 2 HERE

Methodology and Methods

A number of research methods were undertaken to explore students' developing perceptions of and engagement with GIS, as well as changes in their geographical knowledge. In addition, we analysed student reports from the fieldwork enquiry based in Mill Road in Spring 1 (see Table 1 and Figure 2).

Questionnaires

Across this phase of the study students undertook six questionnaires comprising mainly open questions (see Table 1). These explored student understandings of the nature and value of GIS, their use of GIS (through informal and formal learning opportunities), their reaction to any interaction with real-world geographers they had experienced, and their geographical knowledge. The final questionnaire in particular included a range of questions to gain an understanding of geographical knowledge with respect to Maude's typology (2018); for example, one question asked students to give examples of what they did to analyse data in ArcGIS Online in order to consider Type 2 knowledge (that provides students with powerful ways of analysing, explaining and understanding).

Interviews

Interviews were undertaken with students twice: all students were interviewed at the start of the study, and a purposive sample of seven at the end of this phase of the project (selecting a variety of students whose final questionnaire responses showed a full range of engagement with GIS and real-world experts, from highly to not at all engaged). We used individual, semi-structured interviews comprising both direct questioning and discussion following unprompted comments (e.g. Longhurst, 2010). In both interviews, students 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 final interviews, students reflected in more depth on how they had used GIS to support their geographical learning, as well as on the use of real-world GIS experts. Informal interviews were also undertaken with three of the real-world GIS experts to explore the nature of the partnership from their perspective: Katie Hall (ESRI Education), Daran Scarlett (ESRI Defence, National Security and Public Safety sector), and Lance Corporal (LC) Smith from the 42 Engineer Regiment (GeoMentor: see Table 1).

Data Analysis

Analysis of questionnaire and interview data, as well as student work, was achieved through using the CAQDAS programme, QDA Miner Lite combining a thematic and case-based approach to the data, attempting to balance breadth and depth of focus (after Dey, 1993). This comprised two stages:

1) To address research question 1 to consider how the use of real-world experts affected student perceptions of and motivation toward GIS, a process of open coding was undertaken through which a set of classification categories emerging from the data (inductive content analysis). This was an iterative process undertaken a number

of times to increase validity of the coding and blind as to the identity of the student.

2) To address research question 2 and explore how use of real-world geography experts might support students' geographical knowledge, analysis was undertaken using a set of *a priori* codes based on Maude's typology for powerful geographical knowledge (2018: Figure 1). Table 2 exemplifies this coding template along with exemplars of quotations coded for each category from interviews and student work.

In undertaking the research, we followed the BERA's (2011) Ethical Guidelines and obtained university ethical approval. Prior to the commencement of the project informed consent was obtained from all students; this process included providing students with a participant information sheet outlining the purpose of the research, the time that would be involved, and issues concerning confidentiality, consent and the right to withdraw from the project at any time.

INSERT TABLE 2 HERE

Findings and Discussion

This section firstly considers how the use of real-world experts in GIS teaching appears to have affected students' perceptions of the relevance of GIS, drawing on interview and questionnaire data to address research question 1. It then moves on to explore research question 2, taking a thematic approach using student work alongside interview and questionnaire data to explore how using real-world experts supported students' geographical knowledge.

How might using real-world experts affect students' perceptions of the relevance of GIS to geography?

In order to address how the use of real-world experts affected students' perceptions of the relevance of GIS to geography, we will first explore how their understandings of the nature of GIS developed through a range of interactions with these experts. Figure 3 shows the frequency (percentage of mentions) for categories emerging from student definitions of GIS in interviews in September and February. At the beginning of the academic year, of the 15 students taking part in the research, only two stated that they had heard of GIS before. However, during interviews when urged to 'have a guess' at what it might be, nine suggested that it might be computer-related; for example, Gabriella commented "I'd presume a computerised system which presents information that will help geographers and people studying geography to find out information that could help with work" and three were able to link it to spatial data. This suggests some familiarity with GIS as a software package but with limited understanding as to what its purpose might be. It also highlights a lack of confidence with any prior experience they did have; for example, Gabriella asked "I used Digimaps for my controlled assessment, is that GIS?". However, in February, all students were able to provide a definition of GIS with almost all referring not only to its data presentation and analysis functionality, but also to the incorporation of geographical or spatially-referenced data (Figure 3). For example, Eva defined GIS as allowing us to "collect and sort of like show, display and analyse geographical data" and Heather "a way of mapping geographical data … in a way that you can analyse it and compare and layer it with other things". In this way, students appeared not only to have a more nuanced understanding of the functionality of GIS, but were also more confident in articulating this understanding.

INSERT FIGURE 3 HERE

This confidence extended beyond a definition of GIS to being able to use it within their geographical learning. In December, students were introduced to two place studies: the first Digbeth, Birmingham, which was presented by real-world expert Katie (ESRI Education) who prepared a story map and set of activities to explore lived experience in Digbeth; the second Mill Road, Cambridge, through a paper-based information pack and exercise presented to students by their class teacher. The December questionnaire asked students about these contrasting approaches to learning about a place study; eight out of the eleven students who completed the questionnaire (73%) stated that they preferred the use of GIS with two preferring the paper-based approach and one suggesting they found both equally useful. Students articulated why they preferred the GIS approach suggesting "information [was] more direct and clearer to understand. More statistics and more maps and diagrams to manipulate and analyse" (Eva) and "it was more visual so could clearly see data in and around the area" (Reagan). In this way, they found that having information presented to them through the GIS made a wider range of secondary data easier both to access but also to interact with. Reagan's final comment that "it's also easier to use and more fun to explore" further iterates this point and starts to illustrate the way that use of GIS with real-world experts appeared to engage students with the geographical enquiry, thereby creating the motivation to find out more about a place.

INSERT FIGURE 4 HERE

In addition to engaging with Katie through the Digbeth place study, during the latter part of the Autumn term students worked with real-world experts in GIS in two further ways: firstly, through a presentation by Elly Greenway to explain how the Rivers Trust uses GIS in their work; secondly a seminar by LC Smith and Daran describing how GIS is used within the military. Questionnaires following these interactions explored student perceptions of the wider relevance of GIS; quantitative responses are illustrated in Figure 4. All students thought that to some extent these sessions had helped them understand real-world applications of GIS and supported their geographical learning. For example, Heather suggested that encountering more applications of GIS had "helped [her] understand its purpose", while Eva identified that the capacity to "ask questions" of the experts was helpful to her learning.

During the spring term, students interacted with real-world experts twice (Table 1): firstly, to undertake a place study on Mill Road, Cambridge, supported virtually by Katie via Skype with interactive pre- and post-fieldwork GIS training sessions; and secondly, through a seminar by LC Smith and Daran providing first-hand accounts of how GIS was used to support the Defence response to Hurricane Irma within the context of the Storm Hazards unit of work. Following this seminar and completion of their Mill Road enquiry report students were asked to reflect on their engagement with real-world experts across their course. Three key themes emerged: illustrating the relevance of GIS, making sense of how GIS can be used, and inspiring students.

Illustrating the relevance of GIS

The most significant response to questions as to the value of engaging with real-world experts (24 mentions (40%)) was that their use gave students a clearer understanding of the relevance of GIS, both to geography and to their wider lives. For example, Gabriella

commented "it's just showing that it's a real-life tool, it's not just for studying … it really shows how cutting edge it is" and Bailey reflects "it's interesting to see how what we have in geography lessons isn't too much different to what can actually be used in real-life situations". The notion of making geography relevant to students is not new; indeed, the premise of Young People's Geographies is built on the idea that drawing on young people's own concerns makes the subject more engaging which, in turn, better motivates and enables students to learn (e.g. Biddulph, 2011). In this case, students were enabled to "make connections between their everyday knowledge and school geography" (Roberts, 2017, p. 6) through their engagement with experts.

Making sense of how GIS can be used

The second theme emerging from students' reflections on the value of real-world experts was that it provided them with a clearer understanding of how GIS can be used, both within industry and within geography as a school subject. Relating to wider industry use, Claudia commented "it helped [me to] understand how people actually use it in their jobs, because I didn't really understand that before, and real-world applications". Beyond the *where* of GIS use, students also commented on how the use of real-world experts helped them to understand the practicalities of *how* GIS is used (20 mentions, 33.3%). For example, Eva comments "I found out all the different places it's used and how … we use it in everyday life … how important it is and how lots of people rely on it." This benefit became clear through responses to questionnaires asking students to describe how or why GIS might be of wider societal use; all students were able to list at least two wider applications with responses ranging from government analysis of census data to managing flood risk, analysing supermarket sales and aiding military identification of bomb targets. Students also began to illustrate an understanding of the relevance of GIS to their own lives beyond their school geography

through, for example, Googlemaps or geotagging on Instagram. This is in keeping with Daran, real-world GIS expert's aims for his involvement as he commented "I hope that it has raised [students'] awareness of the huge and growing range of geospatial data that is now available and ways in which this can be utilised". Here again, engagement with real-world experts has been marshalled in powerful ways, and is clearly introducing students to the ways in which geographers think about the world.

Real-world experts as inspiration

Perhaps significantly, the third key theme emerging from students was that the use of real-world experts was inspirational to them, particularly presentations by LC Smith and Daran on military use of GIS. Reagan comments:

> they were talking about how they had helped in the Haiti earthquake and it was
> just really … amazing to see how they used GIS … they knew where everything
> was, where was most damaged and where they had to help the most and … it
> was really interesting that they could help so much … just using GIS

Gabriella was also inspired, stating "it really shows how cutting edge it is and how fast it's developing, how it is used in real world situations, and how they are preparing it for the future right now. So that's quite cool.". This aim of inspiring students is in keeping with the aim of GeoMentor involvement with students through the programme (Bednarz, 2016;); indeed Daran provided a rationale for his engagement with schools suggesting "by providing them with real-world examples of how geographical knowledge and GIS can be employed, I hope that we have stimulated their interest in the subject, its value and the contribution it can make to situational understanding". It is this potential impact on student engagement and learning that will be explored in the remaining analysis of the paper through consideration of Research Question 2.

To what extent does the use of real-world experts in GIS teaching support students' acquisition of geographical knowledge?

In order to explore this research question we will consider interview and questionnaire responses in which students were asked to reflect on their work with real-world experts using GIS, alongside evidence from students' work in the form of Mill Road enquiry, using Maude's typology of powerful geographical knowledge as a framework for discussion.

Type 1: Knowledge that provides students with 'new ways of thinking about the world'

Maude (2018) describes Type 1 knowledge as that using meta-concepts such as place, space or environment. Within her report, Gabriella uses a combination of primary and secondary data to explore the notion of sense of place as oppose to perception of place (see full quote in Table 1). A similar discussion emerged within Heather's report who writes:

> These patterns may have emerged as those who are 40 mins away from Mill Road don't have a deep sense of place and understanding of Mill Road as they may only be passing through; however closer into Mill Road you get a greater sense of being an insider to a place ... therefore your attachment will be greater and likely more positive.

It seems through these examples that engagement with GIS through Katie facilitated this thinking for some students, providing the tools with which to ask and answer innovative geographical questions relating to the meta-concept place.

Type 2: Knowledge that provides students with powerful ways of analysing, explaining and understanding

Evidence for Type 2 knowledge within interview and questionnaire data was strong as students discussed how real-world experts supported them to analyse, explain and

generalise their fieldwork data. At the simplest level, Raoul described "we were able to contrast our primary data to secondary data and help prove our hypothesis". Reagan suggested "using GIS made it like easier to compare things that we had thoughts about" and Eva "you could just like layer them up and show relationships between things". This is something that is identified by Katie who suggests that "making links between primary and secondary data sets is easier when there is a visualisation that can be explored, and from there to overarching geographical theory that helps explain what they are seeing". However, evidence for *high quality* analysis and explanation (Maude, 2018) was not prevalent within the student reports themselves; while many presented primary and secondary data cartographically via GIS with some simple or superficial analysis, it was more difficult to identify clear examples of analysis or explanation in which students explored spatial distributions and relationship within the text (as suggested by Maude, 2018). Some appeared to struggle with making links between the primary and secondary data, instead presenting both data sets separately and, thereby, limiting their analysis. Others considered variables such as distance travelled to Mill Road in isolation, attempting to explain them out of context or without recognition of the complex relationships between data. As such, it was often students' capacity to explore relationships between different variables within and between data sets which restricted the depth of engagement with them, something which Kerski (2011) argues would develop with more prolonged use of GIS. This suggests that whilst students have begun to grasp the "skills needed to deal with the complexity of geographical knowledge" (Roberts, 2017, p. 8), further avenues need to be explored to ensure students become fully able to deploy their analysis and explanation as an integrated part of a geographical enquiry.

Type 3: Knowledge that gives students some power over their own geographical knowledge

Gabriella writes that using GIS enabled her to "edit and really tailor the data to what you wanted to investigate"; this is very much in keeping with Maude's description that Type 3 knowledge is about having an answer to *'how do you know?'* (2018). For some students, exploring GIS reframed how students think about enquiry; Claudia explained "I used the data to think about questions, rather than the other way around", suggesting that by displaying primary and secondary data in a range of ways she was prompted to develop new geographical enquiry questions. This is something Katie suggests would be important as a marker for successful engagement with GIS: "my key criteria would be using GIS to formulate and answer questions rather than just to make a pretty map".

This type of knowledge was again difficult to identify across the students' reports. There are some attempts to engage critically with the validity of data; for example, in her evaluation, Gabriella notes "However, a problem encountered was the lack of diversity in respondents, as 77.78% were white, and the majority were of an economically active age" suggesting she is considering the validity of knowledge developed, thereby demonstrating power over her geographical knowledge. In a similar way Eva evaluates the gender and ethnic diversity of interview respondents, using GIS to engage with consideration of how representative the sampling is. However, these are relatively superficial reflections, lacking the deeper engagement with metadata encouraged by Fargher (2017b) through which students would fully explore the roots of geographical knowledge encountered, and not yet demonstrating awareness of how knowledge is developed and tested within the discipline (as suggested by Maude, 2018).

Type 4: Knowledge that enables young people to follow and participate in debates on significant local, national and global issues.

Students referred to significant local and national debates within their reports, from "whether it matters about the amount of independent shops along Mill Road and in Cambridge" (Reagan), congestion, accessibility ("many of the curbs were not dropped and the uneven narrow pavements made it very hard to self propel a wheelchair - these accessibility flaws are limiting the variety of people who can visit Mill Road as certain groups have been unintentionally excluded whom will then begin to form a more negative place attachment" - Heather), and inequality of income distribution. It appears that a combination of personal experience through the field trip and primary data, along with secondary data within GIS, such as Index of Multiple Deprivation and crime, facilitated engagement with these geographical issues. Kerski (2011) highlights the dependency between spatial thinking, fieldwork and enquiry, and both he and Walshe (2018) identify the integral part GIS might have to play in the enquiry process. The fact that GIS has been situated within the use of real-world enquiry supported by real-life experts seems important in supporting the development of students' knowledge in this case. Here, students are able to use real data critically, and through local and national debates, this enquiry is connecting them to their own community (Kerski, 2011).

Type 5: Knowledge of the world

The sense that students were taken beyond their own experience to develop better knowledge of the world emerges clearly throughout the data; as Daran describes "the contribution [made] to situational understanding". Bailey articulates this particularly well through his interview:

> It has helped understanding and visualising and getting a grasp of the place … to start with I had no idea where Digbeth was or anything and then being able to

see where it was in relation to the rest of Birmingham and parts in Digbeth and stuff, it helped.

At a very basic level, students were able to use GIS to develop an informed view that had the capacity to challenge preconceptions and address assumptions of their own subjective views, as outlined by Reagan:

> This data gave me an idea of what Mill Road would be like before I went there which allowed me to compare my own views with those of others and also with data collected.

While the report was based on a place local to students, it still afforded those who had visited Mill Road before the opportunity to engage with it in different ways (see also Dominic's quote in Table 1). This evidence suggests that students' learning has been facilitated by the real-world experts who provided both knowledge and expertise but also engaged and enthused students in different ways so that they have been able to access knowledge for themselves. This makes it a more sustainable approach, as students can begin to transfer this approach to accessing such geographical knowledge to other areas of their studies in geography.

Conclusions

This paper has highlighted that real-world experts can play a significant role in illustrating the relevance of GIS, allowing students to make sense of how GIS can be used both in the classroom (and by real-world geographers), and inspiring them to engage with it to support their geographical learning. However, there are challenges to ensuring that the opportunities of working with real-world experts can be fully realised for the benefit of geography students. In particular, the teacher acting as an intermediary between real-world expert and students is crucial to ensuring that real-world experts can be leveraged effectively to support the development of geographical knowledge. The teacher has a role ensuring that the activities with real-world experts are well-pitched to

capture the attention of students and are complementary to students' geographical studies. Without this, interaction with real-world experts is at risk of becoming tokenistic, with students remaining disengaged from both the experts themselves and the substantive geographical content they are introducing.

The GeoMentor volunteer scheme provides the impetus for real-world experts in GIS to support geography teachers and work with geography students; it also provides a framework for more substantial, long-term cooperation between geography teachers and GIS experts (Bednarz, 2016). Findings of this research support this, suggesting that a more prolonged relationship and programme of support would inherently provide the capacity to begin to tackle the initial issues raised here. In this study, students articulated greater engagement with GIS through real-world experts after several months and three individual 'meetings' with LC Smith and Daran. Continued engagement could also provide the chance to vary the settings in which the real-world experts can support students; for example, further opportunities to interact with students, perhaps through fieldwork or specific assignments (potentially co-created and assessed with teachers), would ensure that the input of real-world experts was perceived by students as an integral part of their geographical learning. The time-scale here also matters, as there is more scope for refining the approach used with students, and adapting input based on students' prior knowledge and feedback throughout the process. Further research is now needed to consider how these interactions might develop over a longer period of time; in particular, what impact might a model of engagement with the same real-world expert over the course of a key stage or even across key stages have on student perceptions of geography or geographical learning?

As illustrated in the discussion, the use of real-world experts in GIS can be seen to support the development of students' geographical knowledge in both direct and

indirect ways. Real-world experts seem to facilitate students' engagement with powerful geographical knowledge (as defined by Maude, 2018) through the activities and interactions that unfold in the classroom. As a result of these activities, it also seems that students are better able to appreciate the relevance of GIS to geography and, as a result, begin to develop awareness of the extent that GIS can be used within their studies to access, present and analyse geographical knowledge. In this way, it also provides intrinsic motivation for students to further engage with 'the geography' at hand. As students become more confident with using GIS as a tool, the focus can be shifted to ensure the development of geographical knowledge is perceived as a central tenet of any such activities and enquiries. This is significant in addressing a barrier previously outlined by Walshe (2018), ensuring that technology can purposefully support geographical learning, rather than detract from it, if marshalled in this way.

Finally, results of this study suggest that real-world experts are also well placed to support teachers and students in realising the educational value of GIS. Fargher (2017b) emphasised the importance of geography teachers being able to engage with how knowledge is constructed in GIS and the types of geographical thinking that can be achieved; it seems clear that real-world experts can play a critical role in unpacking these significant aspects of powerful geographical knowledge for students. They are well placed to marshal real-world examples that illustrate the situated context in which knowledge can be constructed in GIS, and further exemplify the lines of enquiry that are explored in their own professional practice.

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Disclosure statement

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Time	Unit	Real-World Geographer / GIS Input	Research Methods
Autumn 1	Changing Places	• Introduction to GIS • Story map task on a place of students' choice	← Questionnaire 1: initial perceptions of GIS & Interviews ← Questionnaire 2: perceptions of GIS after first lesson
Autumn 2		• Presentation by Elly Greenway (Rivers Trust) • Presentation by Lance Corporal Smith (pseudonym) from the 42 Engineer Regiment (Geographic) and Daran Scarlett (ESRI - Defence, National Security and Public Safety) • Using GIS to explore socio-economic characteristics in Digbeth • Using GIS to explore lived experience in Digbeth with Dr Katie Hall (ESRI – Education) drawing on data from Dr Phil Jones' Rescue Geography project (Jones and Evans, 2012)	← Questionnaire 3: perceptions after completion of story map task Questionnaire 4: focus on talks by industry experts and paper-based versus GIS based activity ←
Spring 1		• ESRI Education supporting preparation for fieldtrip exploring whether there is a positive place attachment to Mill Road (virtual lesson delivered by Dr Katie Hall) • Use of Survey 123 as part of data collection • ESRI Education supporting exploration and analysis of data (virtual stimulus and support session delivered by Dr Katie Hall)	Questionnaire 5: focus on fieldwork enquiry ←
Spring 2	Storm Hazards	• Developing students' understanding of the spatial distribution, frequency, and predictability of storm hazard events using GIS within Storm Hazards topic with support from Lance Corporal Smith and Daran Scarlett • First-hand accounts of how GIS was to support the Defence response to Hurricane Irma and the typical products generated to aid decision making by governments/NGOs	Questionnaire 6: focus on fieldwork enquiry and input by LC Smith and Daran Scarlett & ←

Type of PGK	Description	Example quotation from questionnaire and interview coding	Example excerpt from student work
Type 1	Knowledge that provides students with 'new ways of thinking about the world'	'a way of seeing how new technology is enhancing the study of geography' (Gabriella)	Finally, it can be suggested that people have a positive place attachment to Mill Road as the area is one of the least deprived in Cambridge. This is because residents are less likely to have to struggle to live there. However, Mill Road has generally been perceived by outsiders as traditionally quite deprived. As a result, it could also be suggested that, while insiders have a positive sense of place in Mill Road, outsiders often have quite a negative place perception of Mill Road. Whilst this decreases the overall positivity of the general populous' place attachment to Mill Road, it is important to focus on the sense of place rather than the perception of place in this enquiry, as a sense of place is affected by Mill Road itself, rather than by external agencies such as the media. (Gabriella)
Type 2	Knowledge that provides students with powerful ways of analysing, explaining and understanding	'I think it was useful because we were able to contrast our primary data to secondary data and help prove our hypothesis' (Raoul)	There seems to be a connection between how far someone has to travel to get to Mill Road and the replace attachment of the area. Those that lived outside of Cambridge tended to have more neutral and less positive answers to the survey. For example, two participants lived in Ely and Huntington. These answers may be as a result of not knowing Mill Road well and not have had developed a close attachment and attach a meaning to the area. If the area has little meaning to the person, they are likely to have less positive or specific views on an area such as Mill Road and as a result not share the same positive views of the local residents. (Eva)

Type 3	Knowledge that gives students some power over their own geographical knowledge	'You could edit it and really tailor the data to what you wanted to investigate, so that was good' (Gabriella)	Figure 1 shows 24 of the participants were male and 21 female, this is suggests a good representation of both genders and so represented a mixed population well. However, over three quarters of the participants were white and there were only small amounts of ethnic minorities such as Black and Asian. This suggests the data collected is less representable of the true population as we know Mill Road is known for its diversity and its mixed ethnic groups. Different ethnic groups have different cultures and different experiences of Mill Road (occupation, racism etc) and so being largely white suggests our overall results are bias towards one ethnic group and so not as representable as it could be. To improve this, next time we could use stratified sampling where we make sure we collect the correct proportion of results from each ethnic group. (Eva)
Type 4	Knowledge that enables young people to follow and participate in debates on significant local, national and global issues.	'they agreed that there was a positive place attachment on Mill Road ...but then … there was a question about crime, for example, like saying … 'what do you think puts people off coming?' and barely any people had put crime, like more people	Current debates in Cambridge include the idea that it is one of the most cloned towns in the UK which has been deeply homogenised by chain stores and cafes however the land use survey highlighted the high number of independent stores and businesses which was the majority in comparison to the chain stores, many of which appear to be doing economically well with a strong customer base. (Heather)

		had put congestion and stuff so when you put on the secondary crime data you could see that actually there wasn't [much crime]...it makes sense because the crime in Cambridge is .. even …it's just everywhere' (Reagan)	
Type 5	Knowledge of the world	'to start with I had no idea where Digbeth was or anything and then being able to see where it was in relation to the rest of Birmingham and parts in Digbeth and stuff, it helped' (Bailey)	Mill Road runs through many different areas of deprivation, with some parts being highly deprived and other being not as deprived. This could create a negative perception of place as people from outside the area would see the deprivation rank and think that it is a poor, and possibly rundown place. However, this is not the case for part of Mill Road as there are areas were the deprivation rank shows that the population is not deprived. Therefore, I believe that this piece of secondary data shows a negative place attachment, mainly thinking about how the IMD looks from someone outside of the Mill Road area. (Dominic)

Table 2. Categories used to code questionnaire, interview and student work data during a priori coding against Maude's typology of powerful geographical knowledge (2018). Quotations are chosen to illustrate connections with, rather than a full representation of, each type of powerful geographical knowledge.

FIGURE 1

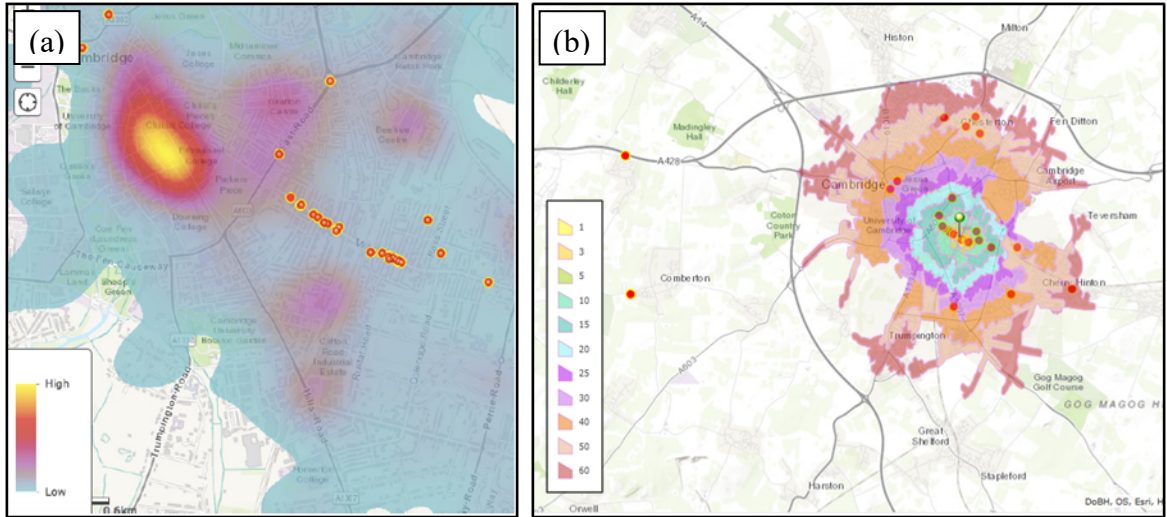| Type of powerful geographical knowledge	Description
Type 1	Knowledge that provides students with 'new ways of thinking about the world'
Type 2	Knowledge that provides students with powerful ways of analysing, explaining, and understanding
Type 3	Knowledge that gives students some power over their own geographical knowledge
Type 4	Knowledge that enables young people to follow and participate in debates on significant local, national and global issues
Type 5	Knowledge of the world

FIGURE 2

FIGURE 3

What is GIS?

Percentage of Mentions

FIGURE 4

Student perceptions of the value of real-world experts

- To what extent do you think use of real-world experts helped you to understand real-world applications of GIS?
- To what extent do you think use of real-world experts has helped you to understand how GIS might be relevant to your life or future career?
- To what extent has use of real-world experts supported your learning of geographical knowledge?

Legend: A lot / A little / Not at all
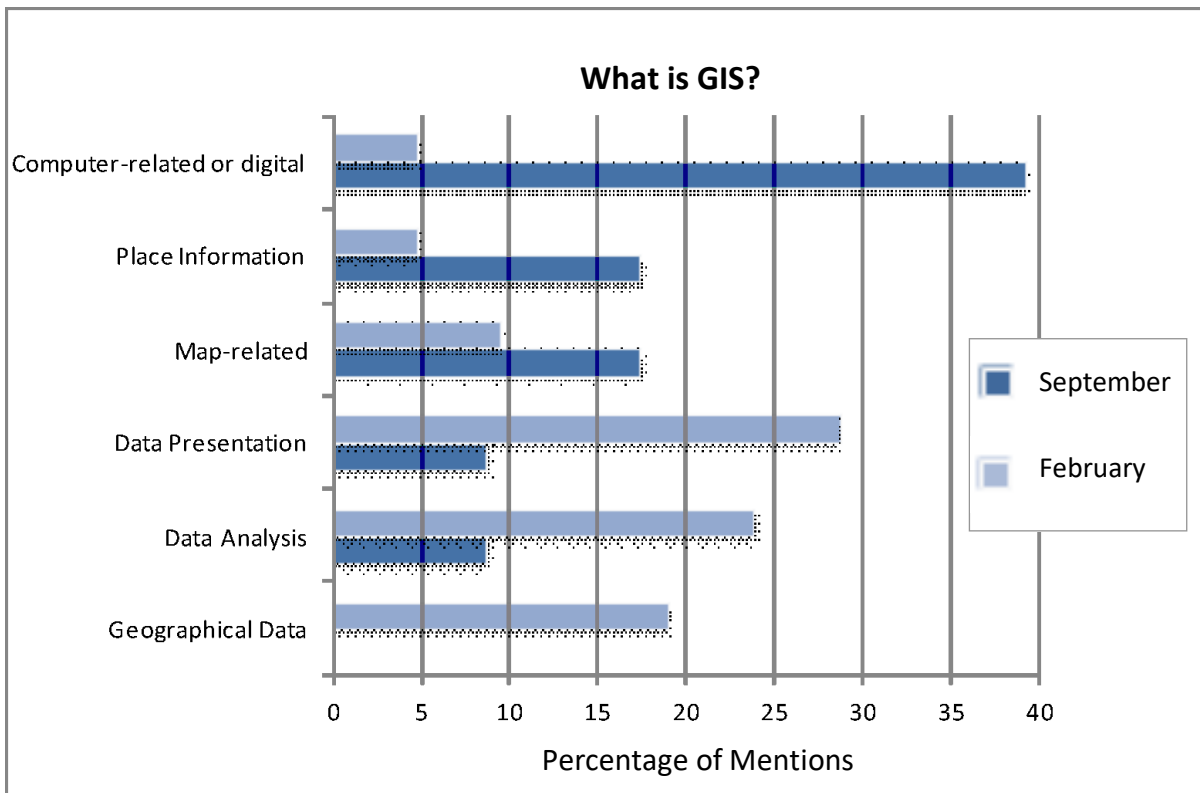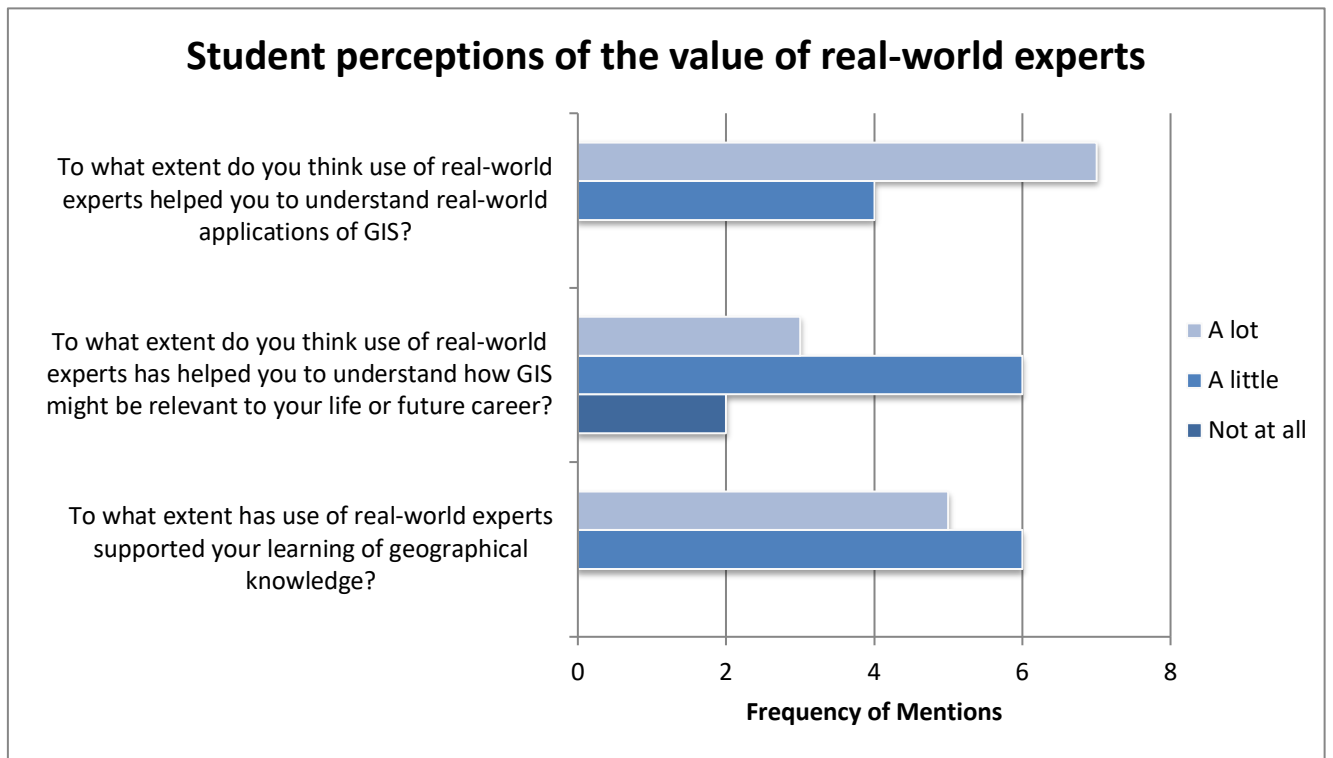
X-axis: Frequency of Mentions (0, 2, 4, 6, 8)

Figure Captions

Figure 1. Typology of powerful geographical knowledge (after Maude, 2018).

Figure 2. Examples of students' GIS work. (a) Use of secondary data to show levels of crime in Mill Road area of Cambridge (hot spot analysis), alongside location of interviews (Heather); (b) Map showing walking travel time to Mill Road (in minutes), alongside location of home address of interviewees (Gabriella). Source: Images taken from ArcGIS Online Copyright ESRI Inc 2017.

Figure 3. Bar chart showing frequency (percentage of mentions) for categories emerging from student definitions of GIS in interviews in September 2017 (dark) and February 2018 (light).

Figure 4. Bar chart showing student perceptions of the value of real-world expert input in December 2017.