

How can GIS contribute to the development of 'Powerful Knowledge' in the Geography Curriculum?

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Abstract

This investigation examines Michael Young's concept of powerful knowledge and considers whether Geographical information systems (GIS) present an opportunity for accessing such knowledge in the geography curriculum. The concept of powerful knowledge may produce fresh impetus to encourage more use of GIS in secondary education if the benefits are visible. To this end, the study also investigates the ease to which GIS tasks can be implemented in lessons. This small-scale evaluative project takes a class of year Nine students through a mapping exercise using ESRI's ArcGIS interface, and then by way of questionnaires determines whether the knowledge accessed could be seen to be powerful, using Maude's (2018) ideas as a framework. Similarly, interviews with a colleague establish whether such lessons could and should be incorporated into the syllabus more regularly. Results suggest that GIS and digital mapping allow pupils to access knowledge which could be considered powerful and that both practitioner and pupils enjoyed their completion. The project concludes by proposing that GIS activities be used more in geography lessons, whilst appreciating that some of the historical barriers to their implementation no longer exist.

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Introduction

Maps are an important part of human endeavour and progress. They allow us not only to feel a sense of place and belonging but to plan for the future. Maps take many different forms; they can be as simple as arrows in the dirt, or verbal directions that paint an image in one's mind, whilst some are incredibly complex, filled with data in layers to unpick and understand. The beauty of maps is that they conjure an image of real-life landscapes, they are respected and tangible. It is still a sign of quality to be 'on the map'.

Human progress has made technology integral to our daily lives (especially in more technologically developed and equitable societies). Like so much else, maps have been adapted and modernised to fit in with this new world order. Although traditionalists may claim that paper maps are best when on a hike, digital maps are rapidly becoming more responsible for the way we travel. From route planning before you leave, to constant tracking of our every movement, digital maps and geolocation are integral in modern life. In the commercial world too, from farmers increasing their yields with more accurate combine harvesting or weather maps, through large industries transporting physical goods across the world and to our front doors, to modern digital advertisers who promote local business close to your location, GIS (Geographical Information Systems) are involved in practically all facets of a globalised life (e.g. discussions of 'time space compression' Harvey 1990). To this end, one would presume that the use and interpretation of such technology (GIS) is surely an essential skill that should be taught in all schools; unfortunately, this is not yet the case. Although specific subjects (E.G. Geography, DfE, 2014a, 2014b, 2013) build GIS into the syllabus (not only in the UK), it is not a discipline that has 'broken through' as necessary (Fargher, 2018). Pupils may pick up a basic understanding organically – i.e. through their own use of technology at home rather than through structured education. Paper maps, on the other hand, are still prevalent across subject areas. Primary classrooms have maps on the wall, many different subject textbooks contain diagrams that could be considered a map.

Over the past twelve months education across the world has had to take a stark turn towards the digital. Covid-19 has meant pupils and teachers being physically separated; completing and assessing work on paper, safely, has been impossible for the majority. It is inevitable that this new, more digital way of learning will become the norm; communication, presentation and marking systems have been implemented which mean that lessons, tasks and assessment can occur at physical distance. Maps are no stranger to this change; mapping and GIS skills can be taught solely using web-based interfaces. This is where my interest in GIS has spurred from; although self-taught and by no means expert, I have witnessed its potential in the classroom. One area of this study will be to analyse the potential for expanding the use of GIS in the classroom and whether the implementation of new techniques is straightforward.

This study is, however, primarily concerned with whether GIS can provide access to 'Powerful knowledge'. At its core, Powerful knowledge "engenders the ability to think abstractly and critically because of its epistemic structure (Rata, 2016). As a result, this increases our understanding of the world, the potential to negotiate the world as it is, and to imagine alternatives (Bernstein, 2000)" (in McPhail 2016).

If GIS can be shown to provide access to powerful knowledge, I am hopeful that there will be a stronger case for integrating it into more lessons in my school. Teachers can be reticent to try 'new ideas' and often have issues with learning new technologies quickly and effectively to use confidently (see

discussion of TPACK below). I will also investigate whether digital lessons can be easily planned and delivered to thus make a case for more inclusion of GIS in the secondary curriculum.

Literature Review

In order to investigate the various elements of this project it is essential to break the main question down into its component parts for clearer definition. Each section can then be critically analysed before delving into the overall discussion; it is my hope that this critical analysis will lead to a more directed focus for the school-based intervention.

The key questions which I have used to focus my review of the literature are:

- 1) What is GIS and how is it used in school Geography?
- 2) What is Powerful Knowledge?
- 3) What powerful knowledge occurs in the geography curriculum?
- 4) What Evidence is there of GIS introducing students to 'powerful knowledge'?

What is GIS and how is it used in school Geography?

GIS (Geographical Information Systems) simply described, is an integrated collection of software designed to query, question, analyse, and interpret data to understand relationships, patterns, and trends (Esri 2016). It is a computer-based tool that allows users to combine interactive maps with geographic data in order to provide information about different locations. Geographical Information Systems integrate and analyse spatial data, therefore providing a digital lens for exploring the dynamic connections between people, their health and well-being, and changing physical and social environments (Cromley & McLafferty, 2002). At its heart, it is the movement of mapping into the digital arena. Paper maps have been the main method for learning geographical information since their invention. Geography education requires the use of maps to understand spatial relationships and thus improve spatial thinking (Collins 2018). There is, however, a distinct difference between simple digital mapping and GIS; confusing the two, GPS, and the geolocation services on apps is common both among pupils and teachers. To do so is to miss the real analytical capabilities of GIS and its potential in the classroom. This is where the majority of the debate around GIS and education centres – whether it is a better, or even beneficial way of building spatial and analytical skills than those which are already in use.

In the UK, the 2014 national curriculum geography programme of study for key stage 3 requires students to be able to use GIS to interpret and analyse places and a range of geographical data (Department for Education, 2013). This is also the case at GCSE and A level for all exam boards – as such it is mainly through Geography that GIS is used. Geography (along with many other subjects) has always used maps to analyse and differentiate data. The fact that GIS features prominently in the national curriculum shows that there are many in the educational establishment who believe in its necessity in the modern world. Indeed, on the Geographical Association's website, it 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). Various studies have been undertaken to investigate the benefits of GIS, however, there is a less than clear outcome and still considerable debate as to its true impact in the classroom (e.g. Akinyemi, 2015).

Sarah Bednarz is a leading researcher of spatial and geographic thinking in a range of educational settings and their links to GIS. Although her work is based in the USA and often involves higher education, it has relevance to this discussion as she sees clear benefits in the implementation of GIS

in classrooms (Bednarz 2004). However, there are examples where she advises caution and points to a lack of empirical evidence that GIS is the panacea some make it out to be. She makes it clear that the research shows little is known about the actual benefits and learning outcomes of GIS (Keiper, 1999; Kerski, 2000; Baker, 2002). Neither does she state plainly that GIS has a positive effect on improving special thinking (Bednarz 2004). In the same work, Bednarz quotes Cuban (1986) in pointing out that:

Radio, television, computers, multimedia, and now hand-held computing devices have, in turn, been offered as solutions to educational problems. Claims were made that each would enhance learning and transform the educational system, yet, in some cases, the system absorbed each without the intended change (Cuban, 1986, in Bednarz 2004 p. 192)

It is certainly plausible that various other media have been viewed as a turning point in education and that GIS may simply be another, soon to be usurped. I would disagree however, simply because of how ubiquitous personal computers and online working has become; a progression exacerbated by the coronavirus pandemic. To this end, I believe that education has changed forever with a movement to the digital. Of course, this doesn't presume that GIS will become the universal method for analysing data. Bednarz and Van der Schee (2006) explain that "GIS software has high technical demands, is a challenge to master, was not designed for a teaching/learning function and does not offer obvious opportunities for teaching/learning to many geography educators." If research cannot pinpoint with absolute accuracy the benefits of GIS in education, why is it becoming more incorporated and prevalent across different education systems? Perhaps it is because there is more work outlining the benefits than the drawbacks. Kerski et al (2013, p. 232) provide a thorough summary of the literature which outlines benefits for both teachers and learners:

"GIS supports constructivist teaching and learning strategies in secondary education such as problem-based and inquiry-based learning (Audet and Paris 1997; Bednarz and Ludwig 1997; Johansson 2003; Landenberger *et al.* 2006; Kerski 2008). GIS provides an opportunity for issue-based, standards-based, and student-centred education in classrooms (Kerski 2003). GIS also allows students and teachers to engage in decision making by studying real-world problems, social and scientific concepts, and processes (Kerski 2008; Milson and Kerski 2012). GIS helps students to think spatially (Bednarz 2004; Lee and Bednarz 2009), ask spatial questions (Nellis 1994), visualize spatial and nonspatial data (Marsh, Golledge, and Battersby 2007), perform spatial analysis (Bednarz and van der Schee 2006), and become active users of spatial data and active learners of geography (William 2001)."

Alongside these skills, as long ago as 1990, incorporating GIS into secondary education was rationalised by Goodchild and Kemp (1990) for three reasons (1) it is a key tool to analyse the environment and solve problems, particularly at the local scale, (2) it enhances student interest in geography and related subjects, and (3) GIS is an attractive technology capable of motivating students to careers in science and engineering. These benefits are desirable for teachers and those who curate curricular across the world's education systems. However, from experience and common knowledge, it seems that GIS is not embedded in classroom activities regularly and still, thirty years on, lacks the presence in the curriculum to provide the advantages mentioned. Bednarz (2004) is the most direct in her assessment. Over various pieces of work she condenses the issue down to two main headlines at an institutional, and perhaps national level. The first is time. Given the limited amount of time Geography is given in the curriculum, and the limited amount of time that GIS is given alongside more traditional learning for exams, is it worthwhile spending so long mastering GIS? The second concerns long-term educational goals i.e. curriculum, instruction and assessment. Until GIS plays a more key role in the above, teachers will not dedicate themselves to the cause. This idea of time (or lack of) is replayed through much literature. GIS can be seen as being too time consuming to produce resources for and thus too time-consuming to fit into the curriculum (Höhnle et al., 2015). Kerski et al. (2013)

explain that the uptake of GIS in schools (internationally) has been slow for just such reasons. At the same time, they highlight regular hardware and software challenges identified by schools but point to the main problem being more societal. The lack of funding and support for professional development is holding GIS education back. Walshe (2018) highlights that it could be teacher's computer skills which are lacking and although the majority of geography teachers have heard of GIS, there is still real confusion about what exactly it requires. Interestingly, Walshe makes the connection between the struggle to implement GIS and Koehler et al's (2013) theory of TPACK (technological pedagogical content knowledge). TPACK explains that teachers must understand how their subject knowledge can be changed by the application of particular technologies. In this instance, few teachers have the TPACK necessary to make the move from paper to digital mapping, let alone move to GIS. TPACK becomes particularly relevant in this debate as it highlights that most software programmes are not intentionally designed for educational purposes, rather for capital gain (Koehler et al, 2013). There are questions over the worth of such link however; Oda et al state that "at the moment little is known about the efficacy of the (TPACK) framework, especially in the GIS domain" (Oda et al 2020, p. 41).

If there are valid reasons for GIS not being fully implemented in education and not being used to its potential, there are also plenty of reasons to be optimistic for the future. Where GIS used to only be possible on powerful computers in specific laboratories, improvements and movements in technology are making complex analytical tools more easily accessible. The impetus for more lightweight and easily accessible GIS is met with enthusiasm in education and the corporate world alike. Fascinating alternatives to traditional desktop tools for geospatial education and communications makes GIS more mobile. This use of Web-based services allows schools to access geographic datasets as well as promoting equality by offering the same tools to all (Kerski et al 2013). Releasing teachers from the constraints of physical GIS software and giving them access to online data has therefore given them more scope for using GIS successfully. "It can be argued that three developments in the use of webGIS in schools are most significant for geography teachers; these are smart mapping, open source data and updated mobile applications" (Fargher 2018, p. 111). Online portals such as ArcGIS (owned and managed by ESRI) take advantage of the use of cloud storage and more powerful personal computing. It allows teachers and pupils to create, view, interrogate and display spatial data very easily (Walshe 2016). ArcGIS offers a simple and easy-to-use interface; digital mapping forms the basis of the platform and there is a plethora of free to download geo-spatial datasets to explore (West and Horsewell 2018) Furthermore, it allows projects to be easily shared or collaborated on and has now been made free to all educational establishments. There is then, real potential for GIS to become a daily and viable part of geography education. To make this a reality, however, more needs to be done.

Henry and Semple (2012) summarized the discussion into five characteristics necessary for GIS to be successfully utilized in classrooms:

1. The GIS software [used in classrooms] should not appear intimidating.
2. A teacher should be able to learn the basic features of the tool in one to two hours.
3. Learning to operate the GIS software should not get in the way of using it for instructional purposes.
4. The geospatial data needed to use the GIS should be pre-processed and included integrally.
5. Technical and administrative support should be available as teachers begin to explore the use of GIS in classroom instruction.

Whilst ArcGIS ticks most of these boxes, it still relies on teachers undertaking most of the training themselves. There is ample literature devoted to the need for GIS training to be improved in initial teacher training but most veers away from the topic at hand. What is clear is that as implementation improves, there will be more training opportunities. Digital resources and knowledge are already being regularly shared across establishments and skills are being integrated into students work more effectively. National GIS competitions are being established; the UK 'Young Geographer of the Year' competition from the Royal Geographical Society allows pupils to submit work completed on ArcGIS

in the form of a 'Story Map' (RGS Young Geographer of the Year Competition Website, accessed 20 Feb 2021). Whilst there are still problematic issues with equality of internet access and training across the UK's educational system, this freeing up of GIS and other digital technology will increase access and interest. For this reason, I plan to use ArcGIS in this study to analyse the links between GIS and Powerful Knowledge.

What is 'Powerful Knowledge'?

There has been much debate around the definition and use of the term 'Powerful Knowledge' (PK), some of it acrimonious. It first appears in literature in Wheelahan (2007) before being introduced into educational debate by Michael Young (2009) and he returns to defend the idea regularly. The fact that there is no easy definition of PK, how to replicate it in specific subjects, or whether it should be identified and separated from other types of knowledge in the first place mean that many authors have shared their opinions on the matter. John White is by no means a lone voice in critiquing PK, but has authored articles refuting the claims made by Young. One of his main concerns is that the term carries a "strong, positive emotional charge" but that upon closer inspection "when we try to see what the term means, the answer is elusive" (White 2018, p. 1). As an educational philosopher, his views concentrate on the theory of PK itself and the use of the term in a wider, over-arching debate about curriculum.

Young discusses PK thus:

"What then is this 'powerful knowledge' and how does the idea apply to schooling or professional or vocational education? I find it useful to make a distinction between 'powerful knowledge' and the related idea of 'knowledge of the powerful'. The latter refers to the knowledge authorised by those in power – and leads to questions about who has the power? Is it legitimate and on what basis? This is what the field I have worked in – the sociology of the curriculum – has focused on; it provides the basis for a powerful critique of existing curricula and how they perpetuate inequalities. However, it focuses on the knower – it does not tell us much about the knowledge. On its own it provides no basis for an alternative curriculum" (Young, 2010, p. 4).

The key to a definition of PK could therefore be try to separate the meaning of the word 'power'. Maude (2016) categorises PK into two main strands; "One focuses on the characteristics that make knowledge powerful, and the other on the power this knowledge gives those who possess it" (p. 2). In short, one which sees that the knowledge itself is powerful through creation by disciplinary communities, and two, what the consequences of gaining this type of knowledge (and thus power) would be on those who possess it.

As a sociologist of education, Young uses the term as part of a broader argument for increasing the importance of subject knowledge in the curriculum. He makes a clear distinction between the everyday knowledge that we gain whilst growing up and the concept associated with academic subjects; those which have been created by experts, specialist communities or governing bodies. Everyday knowledge is context specific whilst PK allows students to generalise beyond their experience (Roberts 2014). For Young (2013), powerful knowledge has two key characteristics: (1) it is specialised, rather than general and (2) it is differentiated from the everyday experiences of learners. Here, he and other writers mention Bernstein's work on knowledge structures (2000, chap 9) which highlights the gap between common-sense knowledge and those of specialists who progress and develop disciplinary knowledge.

Harland and Wald (2018) describe that "Young makes a clear distinction between powerful knowledge and 'knowledge of the powerful' with the latter term referring to those who decide what constitutes

knowledge and who has access to it" (p. 6). They point to the idea that what Young is highlighting is that school curricular are dominated and created by particular groups, political parties or alliances who are using their position of power to generate consensus around ideas or values. This idea that existing school curricular represent the ideals of those with power resonated with many educators and was the main idea which drew me into this discussion. Whilst we will return to the links between PK and Geography as a subject, it is worth noting here that there is tension in this idea, as links between the subject knowledge disseminated in schools and academic disciplines are complex and changeable. Young attempts to clarify the relationship thus;

"the curriculum must stipulate the concepts associated with different subjects and how they are related, whether they refer to energy, matter, literature or historical change. It is the systematic interrelatedness of subject-based concepts and how they take their meaning from how they relate to each other that distinguishes them from the everyday concepts of experience that pupils bring to school, which always relate to specific contexts and experiences" (Young, 2014b: Chapter 3).

Whilst there is much discussion dedicated to the idea of 'Knowledge of the Powerful' there is not time enough here to do the debate justice. I am more concerned with access to knowledge which could be thought of as 'powerful'. The thrust behind PK is to put knowledge at the forefront of education and assert that schools main concern should be to provide pupils with knowledge that is accessible and useable. Roberts (2014) likens Young's ideas to Vygotsky in that "both emphasise the fact that school knowledge can be more abstract, more general, more systematised and beyond what students experience in their everyday lives" (p. 191). Knowledge that is powerful could, at its most basic, be that which makes pupils think differently, or perhaps more critically. Although an over-simplification of a complex narrative, it seems that most authors agree that powerful knowledge should be that which has powerful outcomes for those who access it. "Powerful knowledge refers to what the knowledge can do or what intellectual power it gives to those who have access to it. Powerful knowledge provides more reliable explanations and new ways of thinking about the world and acquiring it and can provide learners with a language for engaging in political, moral, and other kinds of debates (Young, 2008, p. 14)."

In this simplified sense it can easily be seen that Young has an almost egalitarian outlook about knowledge acquisition and that it is school's responsibility to bestow this knowledge upon all equally, providing everyone with the 'power' to access the knowledge (or the skills it fosters) in other facets of their life. There are issues with this line of thinking; whilst Young has defended his viewpoint in several articles, the main concerns about the ethereal nature of the term and our ability to implement it in curricular remain. One of the main critiques of Young's work is not necessarily that PK doesn't or shouldn't exist, it is that his examples lack the heft or visible evidence necessary to become reality. White uses examples from History, Geography, English Literature and Music to show a lack of Powerful Knowledge inherent in each, settling on the idea that "the only subjects that so far meet both Young's criteria for PK are Maths and Science" (White 2018, p. 4). Another argument is that of the central theme in Young's work which dictates that school's main priority is the dissemination of knowledge and that curricular should be subject based. Again, this isn't the place to delve into such broad educational philosophy but it is clear that schools have a variety of goals. Curricular must also be at least in some way centrally planned, complex, and homogenous. There is more to education than the quest for theoretical knowledge.

In this sense, we encounter the main issues with including PK in the curriculum - those of breadth verses specialisation. Young people need to be equipped with the knowledge to understand themselves, as well as function in society; this cannot simply be achieved through academic specialist knowledge. Including this breadth in the curriculum has been difficult, one can see this with the example of citizenship, a much-maligned subject which was "affected by lack of status and momentum

and by pressures on the timetable from core subjects” (Keating et al., 2009, para. 7.2.2). There is also a fear that PK would lead to premature specialisation with pupils never getting the chance to follow certain subjects.

Beck (2013) considers the fact that there is some knowledge, which could empower individuals or groups which would not be beneficial. He mentions the knowledge of how to manipulate others or even intimidate or torture could be considered PK. “An educationally defensible conception of powerful knowledge would therefore need to appeal to additional criteria in order to exclude such morally repugnant forms of empowerment” (p. 9). We can see the challenge to Young’s ideals of a knowledge-based curriculum, which links with the knowledge of the powerful, in that there will still need to be some censure or central decisions about what knowledge is beneficial or allowable. At the same time, there is the accusation that academic knowledge is inherently and by design elitist and esoteric. Beck (ibid p. 12) explains:

“Within scholarly communities that are relatively autonomous from political and commercial influences, structured sets of inter-related concepts within disciplines are required to be logically related, internally coherent, and – crucially – oriented to the ‘problems’ internally identified within each discipline at a particular stage of its development.”

Bernstein goes further and implies that such scholastic communities tend towards narcissism and are self-absorbed (Bernstein 2000). Therefore, the earlier that a pupil engages in such disciplines, the better they will be able to maximise their achievement and gain the highest grade. Conversely, those, or any who miss out on having the choice of such discipline knowledge or come late to a specification will find it more difficult. This links to the previous point about premature specialisation, but is something clearly seen in UK education already. Whitty quotes Michael Gove himself as highlighting this competitive advantage: “Richer parents who can afford it access specific subject teaching earlier rather than later with the most successful prep schools introducing discrete subjects taught by subject specialists before pupils go on to secondary education” (Gove, 2008, in Whitty, 2010 p. 30). Similarly, Catling and Martin (2011) argued that powerful knowledge as perceived by Young is “insufficient in the primary context because it valorises academic knowledge above the everyday or ethno-knowledges that pupils bring with them into school” (Catling and Martin 2011 p. 3). Young states that his ideas are largely aimed at secondary education, but surely for consistency it is vital to apply PK to all phases of the education system. Thus, we return to the original problems outlined with the promotion of PK in the curriculum; those of what it actually is, and to whom it can realistically apply. To find a more satisfactory explanation, I will now look at Geography specifically, and to how various researches claim that it is an ideal candidate for the inclusion of more powerful knowledge. One such work comes from Solem, Lambert and Tani (2013) who, whilst not talking specifically about GIS emphasise that “the powerful knowledge offered by geography education consists of a deep descriptive ‘world knowledge’; a theoretically-informed relational understanding of people and places in the world; and a propensity and disposition to think about alternative social, economic and environmental futures” (p. 220).

What ‘Powerful Knowledge’ occurs in the Geography curriculum?

In order for pupils to access (subject) knowledge considered powerful (by some), practitioners must be able to disseminate information from a position of quality pedagogical content knowledge. There has been much research on the need for teachers to have a deep knowledge of their subject areas (Deleplace & Niclot 2005; Yager 2005; Metzler & Woessmann 2012). “Beyond content knowledge, teachers must have pedagogical knowledge, pedagogical content knowledge, a knowledge of learners, knowledge of curriculum, and knowledge of instructional design and technologies (Shulman 1987; Harris, Mishra & Koehler 2009)” (in Solem, Lambert & Tani 2013 p. 219). One could add technical pedagogical knowledge (TPACK, Koehler et al, 2013) as well and highlight the need for technologically trained and prepared teachers in disciplines such as Geography. It is clear that not all teachers will

have the ability, background or training to be able to make PK accessible for pupils; but that there may be easy steps to making their own knowledge more powerful.

As previously stated, and echoed by Roberts (2014), there is still much discussion needed in order to connect PK with pedagogy of particular subjects. There are, however, some really obvious linkages between the core ideas of PK and those already being taught in the Geography curriculum. Young (2010) advises that PK is:

- conceptual as well as based on evidence and experience;
- provides reliable and in a broad sense provides “testable” explanations or ways of thinking
- is always open to challenge;
- is organised into domains with boundaries that are not arbitrary and these domains are associated with specialist communities such as subject and professional associations;
- is often but not always discipline-based.

As a Geographer, I feel that my subject ‘ticks’ most of these boxes, and there has been much geographically specific discussion as to how to incorporate PK into the curriculum. Roberts (2014) challenges the notion by explaining that Geography education relies on everyday knowledge and not just subject specific understanding. Maude (2016) tries to exemplify what Geographical PK might look like by focusing on Five types of Geographical understanding to prove that it can apply to specific subjects and later (Maude 2020) makes a case for PK being integral to future ways of teaching Geography, through the Geocapabilities project (more on this later). Catling and Martin (2011) look closer at Primary Education and pupils own Ethno-Geographies impacting their access to PK, whilst Virranmaki et al (2019) challenge the current Finnish secondary Geography system to ascertain what type of Geography is taught and whether it could be considered powerful. Whilst this is by no means an exhaustive list, all of these works refer primarily back to Lambert’s (2011, 2014, 2016) initial discussion of the importance of Geographical knowledge in the curriculum. Thus, any assessment of the literature, or indeed the concept that Geography is an inherently ‘powerful’ subject should include Lambert’s assertions. Lamberts views, however, are not based on empirical research but rather arguments taking in views from policy and historical studies. The arguments are cautious in welcoming a change of focus in curriculum away from “generic skills” (2011, p. 243) and “aims-led curriculum planning” (2014, p. 11) which undermined the place of knowledge in the classroom (2014). A criticism, therefore, is that no ‘real life’ examples of benefits are offered, rather he relies on an individual epistemology. Lamberts experience and longevity in the field add the robustness of these views however.

Whilst it should be said that Lambert (2011), like Young, believes that the school curriculum need be focused more on subject knowledge than on generic skills, he advises caution in reducing the breadth of a pupils’ education unnecessarily. It is within these contexts that he makes a case for Geography as a ‘powerful’ subject, endorsing its inclusion in the EBACC (English Baccalaureate). To summarise Lamberts comprehensive analysis of the knowledge that Geography gives feels somewhat reductionist, but at its heart his work believes that “All children and young people deserve the best geographical education therefore, since it contributes significantly to their knowledge and understanding of *their place in the world*” (Lambert 2011. p. 7 my italics). Although a powerful concept, one could argue that there is more powerful knowledge out there; for example, knowledge that enables them to change the world or their place in it. Slater et al. (2016) acknowledged Lambert’s definition of PK but worried that he didn’t stipulate “what it actually is” (p. 191). Lambert (2016) responded that it is not the curriculum content that matters, but “in what way is geography powerful knowledge” (p. 192). He also asserts that either a lack of, or poor-quality Geographical knowledge has a deep impact upon the curricular experience of pupils (Lambert 2011). I would agree that any Geography which serves this purpose fulfils Young’s ideals. One issue is the lack of understanding held

by those outside the community or even education administrators of what Geography contains (Maude 2016). Whilst it is clear how powerful geographical knowledge can be to those on the 'inside', proving it externally is a different matter. There is an international movement trying to prove just this case – named GeoCapabilities. Built upon the idea of 'Capabilities', a term originating from the work of Amartya Sen (1995) and Martha Nussbaum (2011).

Solem, Lambert and Tani (2013) introduce that Geocapabilities "long-term goal is to establish a conceptual rationale and empirical basis for building transatlantic collaborations in geography education, eventually expanding to other world regions" (p. 215). Since its inception the project has moved through three phases, as described by Biddulph et al (2020); "The focus of phases 1 and 2 of GeoCapabilities was geography teachers, their role as curriculum leaders and their understanding of and engagement with three key ideas: 1. 'powerful disciplinary knowledge' (PDK); 2. 'Curriculum making'; 3. A 'Future 3 curriculum' rooted in a social realist view of knowledge. Phase 3, seeks to develop and extend this work by examining the practical application of a GeoCapabilities approach" (M. Biddulph, T. Bèneker, D. Mitchell, M. Hanus, C. Leininger-Frézal, L. Zwartjes & K. Donert (2020) p. 261). Whilst there isn't the time or space to delve into the theoretical background of the project, at its core is the link between Powerful knowledge and Geography. Aligned with the general external view of the subject they propose that it is the "theoretically-informed relational understanding of people and places in the world" (Solem, Lambert and Tani 2013 p. 219), linking PK to Geographical understanding by way of Walshe's (2018) categories (elucidated below). The project is international and through analysing Geographical standards in England, the USA and Finland the authors point out that "a capabilities perspective on geography goes beyond a focus on competencies by describing a subject that can contribute in specific ways (and no matter how it is configured in national standards) to young people's powerful knowledge" (Solem, Lambert and Tani 2013 p. 220). Here then, we have a variety of authors and collection of ideas trying to deliberately prove that Geographical knowledge is powerful. Later, Uhlenwinkel et al (2017, p. 336) introduce the term powerful disciplinary knowledge (PDK). They conclude that: "...the powerful disciplinary knowledge in all four countries is described in terms of world knowledge and understanding the world using geographical perspectives such as looking at human and nature interactions, using the concepts of scale and of local-global relationships, studying geographical issues (e.g. climate change) and linking these to personal (or individual or communal) choices". Fargher (2018 p. 5) describes "The GeoCapabilities approach also assumes that the expansion of specific human capabilities is followed by human empowerment to think and act in ways that fulfil one's future prospects. Fundamental to GeoCapabilities thinking is an emphasis on a progressive, subject-led approach to teaching school geography particularly through the development of powerful disciplinary knowledge (PDK)". Maude (2018) uses this basis to interpret Young's idea in a different manner by suggesting five types of Powerful Geographical Knowledge (PGK) compared with PDK in the GeoCapabilities project. I will return to these in the next section as I believe they could act as selection criteria for teachers wanting to implement content for teaching PGK (Maude 2018) and will help to design an intervention in school to link GIS use with PK.

There is, however, real tension between PK (or PGK) and the breadth required to teach Geography at secondary school level. Young (2011, 2013) himself uses some Geographical examples to clarify his ideas about different knowledge (namely cities; e.g. Auckland and London), stating that teachers, unlike pupils would be interested in "how they differ, their history and how they change" (Young, 2013a, p. 110–111). However, Roberts (2014) explains that this kind of knowledge can not necessarily be applied to all cities because they are all different, all have different history and all change. There is no scope for generalisations about cities as important ideas such as the causes of inequalities could be missed. Roberts (ibid) also disputes the claim that Geography is powerful because it is not necessarily 'real' (Young and Muller 2013, p. 241). Although focusing on human Geography, she explains that pupils only experience the "real world only on the rare occasions when they work outside the classroom or if their direct experiences of the real world are used as an object of study" (p. 200).

Pupils are rather exposed to various representations (photos, videos, articles) particularly chosen for that topic or subject area. Roberts also states that “disciplinary knowledge about urban geography does not have the characteristics identified by Young and Muller, nor would other aspects of human geography” (p. 201), but does explain that physical geography could as it is more concerned with reliabilities and processes. In this sense, we return to White’s (2014) critique that PK only suits Maths and Science.

What evidence is there of GIS introducing students to ‘Powerful Knowledge’?

As examined in the previous section, whilst there has been much research linking Geography to PK, little has focused on providing teachers with a blueprint of how to implement it into their lessons. This is an area which I believe warrants further examination; can specific skills be said to be fundamentally ‘powerful’?

Geography curricular offer a broad skill set, however, Maude (2018) explains that “there is no definitive set of principles (which I think of as generalisations) and skills that should be taught, and some of geography’s traditional skills have been rendered obsolete by technological change” (p. 184). In a comparison of English, American and Finnish Geography education for the Geocapabilities project, Solem, Lambert and Tani (2013) make the conclusion that whilst different in scope and practice, there are similarities that Geography “equips individuals with the ability to think and reason using diverse forms of locational data and knowledge of human and natural systems in different (and sometimes unique) place contexts” (p. 224). They explain that this allows creative and critical thinking and empowerment. This tallies with earlier work by Bednarz and Van der Schee (2006) which explains that GIS empowers students to think and ask spatial questions and to perform spatial analysis. Virranmaki et al (2019) consider that “Geographical knowledge is seen above all as spatial knowledge” (p. 112), whilst asserting that maps and mapping is a cornerstone of assessment of this skill by Geography teachers. Whilst surveying Geography teachers in Finland, they conclude that “it is important to be able to understand the world as a diverse place and maps were the most effective teaching method for achieving this. Maps are both produced and interpreted: it is important that they (pupils) have some kind of understanding how to make and understand maps. And above all I encourage them to draw maps” (p. 112).

Maps have long been part of geography because they allow teaching in a way that connects different elements, making pupils understand and apply knowledge in new contexts. Bednarz, (although writing before PK was brought into debate), when talking about GIS in education wrote, “if knowledge is power, knowing abstract knowledge is more powerful and helps produce independent, critical thinkers. It is clear that these findings need to be incorporated into the development of a pedagogy appropriate for GIS” (Bednarz 2004 p. 198). If we revisit Lambert (2011), he extolls the virtues of digital mapping and increasing ICT use, explaining that geography keeps pupils’ options open post GCSE in the UK, as pupils can be “inspired by challenging and engaging questions concerning society and environment, drawing on diverse sources and data; and based upon deep description and scientific explanation of contemporary change” (p. 249). Others pick up on this theme and explain that these critical skills formed in GIS education will benefit pupils in later life. I discussed the educational movement towards digital skills and technology in the first section, and here we can tally with Fonseca et al. (2002) who explain that professionals are turning away from paper-based maps and GIS is being used not only to visualise data, but to depict complex interrelationships among data layers. Audet and Ludwig (2000) agree that GIS develops critical thinking skills, which will in turn make pupils better employees for whatever vocation, an idea one could consider as empowering, as well as developing PK.

There are some dissenting voices in the literature however; Kerski (2000) found no real difference in critical thinking skills between a group using hands-on mapping and a group using GIS. There is a lack of concrete empirical evidence for GIS leading to critical spatial thinking, as Fargher (2018) explains

that whilst GIS might support students to make sense of spatial information, it is distinct from teaching students to think geographically in a broader sense. In order for GIS to be properly labelled as powerful, there needs to be investigation to consider the ways in which one could develop these knowledge types. Walshe (2018) provides possibly the clearest, most direct and concise analysis of whether GIS in education could be considered powerful by linking Maude’s (2016) typology of Powerful Geographical knowledge:

Type of powerful knowledge	Description of geographical concept
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

Table 1 – Types of powerful knowledge found in Geography (Maude 2016).

Walshe proposes that GIS could be used to develop Type 3 knowledge, whilst “being able to access, visualise, interrogate and analyse Index of Multiple Deprivation (IMD)² data might provide a platform from which students could engage with significant national debates on social inequality (Type 4 knowledge)” (Walshe 2018 p. 47). She goes on to caution that these ‘powerful’ ideals could only be realised when combined with expertise from a teacher who’s carefully developed pedagogies support pupils to think geographically, linking to earlier discussions of PCK. I believe that GIS education, if planned and used correctly could potentially apply to all five of the above categories and this is where I plan to direct this investigation.

At this point, we should counterbalance these ideals and return to the earlier discussion of the variety of reasons why GIS has not become more ubiquitous in secondary geography education. Beneker et al. (2015) simply conclude that “teachers do not have clear, inspiring visions about geography education” (p. 366) and Bednarz (2004) denigrates the fact that few teachers are aware of the growing importance of maps and mapping science. From experience I can attest that too few Geography teachers are excited about spatial thinking and reasoning when taught through maps. Bednarz (2004) elucidates her point thus: “Teaching *with* maps means using maps in instruction to help students learn key geographic concepts and relationships. Teaching *about* maps means providing students with the skills and understandings required to read, interpret, and produce maps. The map skills components of most US textbooks and other map-teaching materials focus on teaching *about* maps and are often dry, skill-oriented, and not well connected to the real world. Few textbooks or other teaching materials offer teachers concrete strategies to teach *with* maps” (p. 198). In this context one can see a similar trend with GIS in education. Whilst teachers have heard of it, they’re not necessarily interested in

teaching it. Much has changed since Bednarz published, yet in an increasingly digital world, there remains no excuse or reason for GIS not being more embedded in the geography curriculum. The universal nature of digital globe technology and the sheer amount of free to download applications for phone or tablet mean that pupils already have a basic knowledge of the systems at use.

In this sense, better use of GIS could potentially allow access to PK and one could develop a framework for empirically testing whether certain tasks empower pupils to think like a geographer. To this end, as well as trying to link GIS to PK, I will be trying to provide an example of a lesson task which conveys this knowledge and is implementable by practitioners. At the same time, it is clear from the literature that PK is a contentious term and any intervention trying to link it to an increased use of GIS will be difficult to demonstrate. However, there seems to be enough of a gap in the literature for an empirical study to attempt to assuage this doubt with some form of evidential approach, whilst also considering that using GIS more effectively and widely is a necessity. It is with this in mind that I approached the problem of producing research questions which could investigate both access to PK and GIS inclusion in lesson time simultaneously.

Methodology

Framework

In order to decide on the best path for an intervention involving PK and GIS, further literature was investigated to clarify the potential of various paradigms and methodologies before the path ahead could be forged. As discussed, the desire to investigate the concept outlined comes from a personal perspective and is designed to influence my own pedagogy rather than inform whole school changes in the first instance. Whilst it is hoped that the intervention will lead to positive results, the necessary small-size limits the potential impacts without repeat investigation on a larger scale. The investigation is intended to interrogate Walshe's (2018) idea that GIS could be used to develop access to PK according to Maude's (2016) five categories of 'Geographical Powerful Knowledge'. These claims are only brief examples and Walshe does not provide any empirical evidence – rather she is postulating from a position of experience. Her thoughts sparked an idea that a small-scale, personal and evaluative approach would be most effective in investigating the claim.

Due to the educational setting of the intervention and the necessity to involve others (pupils and colleagues) my early consideration of a positivist outlook was discarded after consulting Cohen et al (2017 p. 16): "the difficulty in which positivism finds itself is that it regards human behaviour as passive, essentially determined and controlled, thereby ignoring intention, individualism and freedom, i.e. As suffering from the same difficulties that inhere in behaviourism". The point here is that the more you try and control variables as if in a lab, the more artificial results will actually be. In order to find any connection between the two main tenets of my investigation, participants will need freedom to choose how to undertake their work and give their opinion. To understand how pupil's react to a new task or stimulus, a more interpretive method would need to be created so that I could understand the subjective world of human experience and retain the integrity of the phenomena being investigated (Cohen et al 2017). People (especially children) interpret situations through their own agency, always learning from experiences; any research has to have an awareness of this. Although I am interested in the views of pupils, the project need not be weighted heavily toward the ethnographic, as it will be necessary to measure the success of the intervention task.

A more postmodern approach was also considered as among other criteria, Jameson (1991) explains that postmodernism has several distinguishing features, some of which rang true for the type of study it would be necessary to undertake:

- The importance of the local, the individual and the particular.
- The view of knowledge as a human, social construct.
- Multiple, sometimes contradictory, yet co-existent interpretations of the world, in which the researcher's interpretation is only the one out of several possible interpretations.
- The recognition that researchers are part of the world they are researching.

The small-scale nature of this project and the idea that PK is so contested led me to ally with the above ideas. The understanding that I am basing this intervention on my own interpretation of the benefits of GIS made me consider that others clearly have their own view point and this needs to be taken account of. Closely discussing issues with colleague(s) and discussing other points of view or attitudes will be essential to make conclusions more valid. What was clear after my initial consideration was that planning and conducting educational research should not follow simple recipes (Cohen et al 2017) as it is a complex process. There was no framework or plan for such a study that I could follow, so an independent, individual investigation was needed to decipher links between phenomena. To this end, when approaching the problem at hand it was decided that a mixed methodology approach, engaging

both quantitative and qualitative data would be most suitable. Fetters and Freshwater (2015) suggest the synergy of quantitative and qualitative offers more than the individual components, Creswell and Plano Clark (2011) agree that the intention of mixed method approach is to give a greater understanding of the topic or problem in question. Leech and Onwuegbuzie (2009, p. 265) explain that it “involves data collection (both quantitative and qualitative), analysis and interpretation of studies that address a particular phenomenon”. This led me to understand that some ‘numerical’ analysis would be needed alongside more subjective view-points in order to increase validity. Yin (2006) argues that the stronger the mix of methods, the stronger the benefits of mixed method approaches (p. 46) and so I intend to have a thorough mix of methods and instruments involved. Greene (2008, p. 8-10, in Cohen et al 2017) organised discussion of mixed method research into four domains:

- Philosophical assumptions and stances (assumptions about ontology – the nature of the world – and epistemology – how we understand and research the world, and the warrants we use in validating our understanding);
- Inquiry logics (e.g. purposes and research questions, designs, methodologies of research, sampling, data collection and analysis, reporting and writing);
- Guidelines for practice (how to mix methods in empirical research and in the study of phenomena);
- Socio-political commitment (what and whose interests, purposes and political stances are being served).

In this sense mixed methodologies apply to different paradigms and are not solely about the methods used. It is not only about what is mixed but at which stage the mixing takes place (Cohen et al 2017); the freedom that this approach offers is one factor which drew me towards it. It was therefore decided to have mixed methodologies to answer two fundamental questions (thus mixing methods and having mixed inquiry logistics); one concerning the ease of implementation of GIS and one concerning whether the use of said GIS allowed access to PK.

Denscombe (2014) mentions the use of triangulation to increase the accuracy of data and reduce bias; triangulation will come from having a variety of methods completed. There are some, however, who don’t see the need for categorising different strands of research any longer, Hammersley (2013) goes as far as to suggest “quantitative research and qualitative research are no longer useful categories” (p. 99). This more pragmatic approach was thus considered ideal as both inductive and deductive reasoning could then take place, the research then becomes driven by the research question (Cohen et al 2017) - an idea which I was endeared to having had a good idea of my direction of study for some time before the intervention; this initial thought “should lead to action, prediction and problem solving” (ibid. p. 35).

Pragmatism adopts an eclectic approach “drawing on positivist, post-positivist and interpretive epistemologies” (Cohen et al 2017 p. 36); it is not a sloppy unprincipled approach (Chatterji 2004), it has its own rigour in that the research must answer the research question(s). Certainly, the research questions in this instance will influence the methodologies and in return will demand to be answered. There is also some discussion that mixed methodology approaches can be confusing or even irreconcilable as the rational between component parts are very different (Hammersley 2013). Bergman (2011a) explains that the term ‘mixing’ is wrong as one cannot mix that which cannot be mixed. He argues ‘blended’, ‘meshed’ and ‘combined’ (p. 272) would be more appropriate. This confusion should, however, not stop one moving forward with mixed methodology research (Mertens and Hesse-Biber 2012). If we are keeping the distinction between the two, discussion then moves onto which area of research should have dominance or whether they should be equal in weight. In this instance, it was decided that qualitative data will have more weight to answer the research questions. Creswell and Plano Clark (2011) identify six mixed methodology designs; their convergent parallel

design (p. 69-79) uses both quantitative and qualitative data collected independently and in parallel with each other, which then converge, giving triangulated data to answer the research question. This outline fitted my initial ideas and gave the freedom to interrogate the issue from different angles, so was the framework from which an intervention was designed.

Whilst analysing the literature about the best approach for such an investigation, the comparisons and similarities between research and evaluation were exposed. Although there are similarities, there are also differences and many of the ideas that were being formed in preparation matched definitions more of a research evaluation approach. Mathison suggests that evaluation is concerned with how well something works; research is concerned with how something works (Mathison, 2007); they also go on to explain that “evaluation is used for micro decision making; research is used for macro decision making” (2007, p. 191). In both these senses, the nature of my investigation would suit more of an evaluative approach than it could be classed as research. Arthur and Cox (2014) classify the two differently by saying that research seeks to predict what will happen; evaluation concerns what has happened or what is happening – similarly when presented under such a microscope my initial intervention idea fit more with evaluation than with research in that I aim to understand what is happening at a micro level and will not seek to make any predictions. At the same time, Cohen et al (2017) explain that “research and evaluation are not mutually exclusive binary opposites, nor, in reality, are there differences between them” (p. 81). Patton (1998) also argues that differences between research and evaluation are often arbitrary – thus it may be that making such a clear distinction in the planning and design of any such intervention may be unnecessary. Using the convergent parallel design mentioned above (Cresswell and Plano Clark 2011) is then still valid. Cohen et al (2017) use literature to explain that evaluation is used more often by policy makers and that it “has to take to task any notion that quick fixes from interventions ‘work’ straightforwardly, or at all” (p. 82). This is a recognition that what works is often due to the complexities of participants and the environment so the evaluation comes to focus on which parts of an intervention work well, or less well, and why. Also, any benefits perceived for one individual may be different for another, and the scope of the intervention may be non-replicable. In this sense, whilst a small-scale intervention is a necessity, there is little current desire to make it scalable or to repeat it with more students – an entirely new intervention would have to be conceived which would satisfy the demands of a larger scale. Pawson (2013) notes Rossi’s ‘iron law’ (p. 12) which states that the “value of any assessment of the impact of a large-scale programme is typically zero” due to the personal and interpersonal dimensions of any intervention. The intervention planned, therefore would be a small-scale evaluative approach. Punch (2009) supports that this as effective because it is likely to:

- be local – rather than regional or national;
- involve a single evaluator – or possibly a small team of two or three;
- occupy a short timescale – perhaps to be done in between one and six months;
- have to be run on limited resources;
- take place at a single site – or possibly a small number of related sites.

Having an evaluative approach will allow the research to be personal whilst gaining the views of participants and their perceptions. Hoyle (1986) states that evaluation data are used to bring resources into, or take resources out of, a department or faculty; which explains the exact nature of the intervention being planned – that is to increase the use of GIS as a resource. If successful then there would be scope to redesign a larger investigation to inform any potential policy looking to increase the use of GIS in the Geography curriculum.

As deliberated in the literature review, the basis for deciding whether PK had occurred and was measurable would be based on Walshe’s (2018 after Maude 2016) discussion linking Geographical

theory to PK. The table below highlights the concepts which I will aim to investigate using GIS software and an intervention.

The figure originally presented here cannot be made freely available via ORA because of copyright. The figure was sourced at Maude, A. (2016). What is powerful knowledge and can it be found in the Australian geography curriculum? *Geographical Education*, 28, (p. 18–26).

Table 2 - Types of powerful knowledge found in Geography (Maude 2016). Highlighted are those proposed to be used in the investigation.

Whilst this small-scale intervention will only be able to acknowledge some of the types of PK explained above, the range of issues defined by this typology of PK offers potential for further research.

Research Questions

A twofold investigation into the implementation of GIS and whether that GIS allowed access to PK was planned. As previously stated, the research questions will determine the methods of data collection to be used in carrying out the evaluation. Although I would not go so far as to claim to ‘prove’ that GIS and PK are linked, I will be investigating and analysing the possibility of causality, but am aware that, as Robson (2018) explains; “In the real world, there is no guarantee that even the best-planned design will actually deliver what you need” (Robson 2018 p. 70). Cohen et al (2017) explain how difficult it is to establish causation. It may be “present but unobserved and indeed unobservable, particularly in the presence of stronger causes or impeding factors” (p. 96). The literature shows that there is still a varied debate about the effectiveness of GIS implementation in geography education, as well as there being consternation concerning the validity of the phrase or idea of PK at all – some will thus see half of the investigation as void as they do not believe in its existence. Nevertheless, two strands of investigation were to be interrogated and triangulated.

West and Horswell (2018), explain that ArcGIS (available for free for educational establishments) has the power to transform the teaching of GIS in UK secondary schools; it provides an interactive but data-rich experience for students. Similarly, Fargher (2018, p. 2) suggests that Web mapping is more intuitive than previous versions of GIS with user-friendly interfaces which do not require a great deal of expert GIS knowledge to use. For this reason, I will be using the ArcGIS system as a base to answer the following two questions:

1. What Challenges are there to implementing GIS in the geography curriculum? (RQ1)
2. Does using GIS provide evidence of access to ‘Powerful Knowledge’? (RQ2)

Although there are two slightly different interests here, as discussed previously a mixed methodology approach will be used to analyse various factors and then to combine (triangulate) the two. The fact that different methods tend to have different strengths and weaknesses makes a strong case for multiple-method evaluations, where two or more different data-collection methods are used when seeking answers to a research question (Burch & Heinrich, 2016).

Research Design

Intervention

All pupils involved in the study had knowledge of the ArcGIS platform through previous learning. At the beginning of year 9 pupils are taught a topic on Antarctica to introduce them to the main workings of the technology. These lessons were conducted over a term which allies with Johannsen's (2006) advice that it is necessary to revert to the teaching of GIS before using it in the classroom. The intervention resources available free online from ESRI (owners of ArcGIS). I adapted the task, with collaboration, tailoring it to the students being taught. Shin (2007) promotes keeping the GIS simple, as over-complication leads to frustration; this would certainly be true with year 9 students. Thus, an individual task was chosen over a more complex series of tasks or a topic sized scheme of work. In order to design the task, Henry and Semple's (2012) five characteristics necessary for GIS to be successfully utilized in classrooms were considered:

1. The GIS software [used in classrooms] should not appear intimidating.
2. A teacher should be able to learn the basic features of the tool in one to two hours.
3. Learning to operate the GIS software should not get in the way of using it for instructional purposes.
4. The geospatial data needed to use the GIS should be pre-processed and included integrally.
5. Technical and administrative support should be available as teachers begin to explore the use of GIS in classroom instruction.

As referenced, literature supports the view that ArcGIS is accessible and potentially powerful addition to the classroom, so I was keen to use it to design the intervention and improve my own pedagogy. In order to investigate whether an increased use of GIS could be linked to PK, an intervention was planned to take place over a course of a couple of lessons, analysing the links between energy consumption by country and global population density. The topic was considered using Fargher's (2018, p. 7) assertion that "pupils should be given the best intellectual opportunities to become knowledgeable about complex issues such as human-induced climate change, population pressure and complex geo-political shifts". Due to the issues of the Coronavirus Pandemic and the national lockdown, as well as time and curriculum constraints, only a single lesson could be analysed, in May 2021.

Before the task, pupils completed a questionnaire to ascertain their understanding of the issues surrounding global energy supply and population density. During the task, pupils had to follow instructions from a video (prepared by myself) to access ArcGIS, navigate to the digital mapping software and investigate the 'Living Atlas' section. The instructions then went through how to research different information 'layers' and add them to a base map, whilst changing aspects of the key to ensure they were unique and individual. Pupils then had to answer the questionnaire with identical questions to interrogate their changing knowledge and understanding of the content. Pupils were then asked to complete a summary question on a Likert scale to give their opinions of using ArcGIS. Interviews with pupils were considered but rejected because they are technically and conceptually difficult (Basset et al 2008). At the same time, time and pressure from other year groups undertaking internal examinations due to cancelled external exams absorbed teacher's time and concentration; further interrogation of opinions during this period was impossible.

After the initial task intervention, a colleague was asked to conduct the same lesson with their class of similar size and ability. There was then a semi-structured interview conducted with said teacher to discuss the challenges of implementation of the intervention as well as their opinions on the learning that took place. Although the teacher in question was not an expert in PK, their willingness to

implement GIS and record the benefits to their class was beneficial to the overall view and thus could be added to the conclusion.

Ethical Considerations

The study involved human participants, notably young people, which required particular ethical consideration as the assurances necessary for safeguarding are enshrined in law. To comply, an application stating the title, RQ's and the possible action was submitted for ethical approval to the Central University Research Ethics Committee (CUREC). Following approval, (prior to commencement of research) the Head was presented with a letter outlining the study and aim of the research. Specific measures to obtain consent from teachers and students are outlined in the table below.

Instrument/Purpose	Ethical Consideration	Way in which consideration was addressed
Online Questionnaires	Confidentiality, traceability and anonymity (Cohen et al 2018)	Use of 'Microsoft Forms' as it requires individuals to log in securing their answers from anyone else. Although not fully anonymous, pupils are used to the system, using it regularly in school and were warned that their names would be visible. Any information used from the questionnaires was anonymised and pseudonymised (BERA 2018).
Online Questionnaires	<ol style="list-style-type: none"> 1. Right to withdraw consent at any stage without prior warning or reason (Cohen et al 2018) and to know the aim of the questions. (BERA 2018). 2. Time strain on respondents (Cohen et al 2018). 3. Researcher – participant power relations (Cohen et al 2018) 	<ol style="list-style-type: none"> 1. Pupils were reminded of their right to not engage with the research if they didn't want to. They were given to option to not answer, or answer in whichever way they wanted to. The full reasoning behind the research was explained to students before the intervention began. 2. Questionnaires were designed to be short in time and easy in nature. 3. Role of researcher was made explicit. Questions designed to be open so that pupils could answer in their own way.
Interview	<ol style="list-style-type: none"> 1. Make teachers aware of what the project involved BERA (2018). 2. Disclosing information if illegal information were found. 3. Overfamiliarity (Lichman 2013) 	<ol style="list-style-type: none"> 1. A discussion prior to the intervention was carried out to explain the purpose of the research and confirm participation. 2. Participant was made aware of the situation following BERA's guidelines (2018). 3. Professional standards were maintained during the process.

Recording of Interview	Safe data storage (BERA 2018)	A recording was completed via Microsoft Teams and stored on a password protected personal computer. Recordings were backed up on a personal, password protected, cloud-based storage system.
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Table 3 – A Summary of Ethical Considerations.

One of the main concerns when working with young people in a school is the power relationships between teachers and pupils. The intervention was designed in order to pass Milbourne’s (2009) three tests for participatory research: young people trusting adults; adult power-holders trusting young people and the need to promote wider trust in young people’s abilities. That is, if the pupils trusted in me and my motives they would not only be willing to be involved, but also to be truthful and give honest answers. This would minimise the Hawthorne effect and lead to more reliable results. Indeed, due to their desire not to have their answers used, three pupils’ results were withdrawn from the data set. Similarly, the fact that I was working with a colleague who I do not directly manage allowed more freedom, so that they felt comfortable giving honest opinions on ArcGIS and its implementation in lessons. I was sure not to try to undermine the teacher’s classroom ability or methods and allowed them to undertake the task in whichever way best suited their style. To this end I didn’t watch or analyse their lesson, or the progress of the pupils taught. I was simply seeking the colleague’s opinion about the implementation of the task and whether it would be repeatable or scalable.

Collaborators

An initial conversation was had with one other member of the Geography department (Teacher A) to enquire as to their willingness to be involved in the intervention. During this first meeting the teacher was informed of the reasons behind the study and its relation to my Master’s degree. Questions concerning the use of GIS and their desire to become more involved were asked and they agreed to take part in helping to design and deliver the session. Subsequently they were engaged in planning sessions and aided the design of the task that was produced and completed by pupils. Teacher A is relatively new to the profession and has had previous jobs outside of education. Some GIS training was provided during their initial teacher training and they have been implementing various tasks using GIS throughout their short career.

Participants

It was decided that only one group of pupils would answer questionnaires where two sets would complete the task. Teacher A’s class completed the task but were not asked to complete the follow up questionnaires, this was due to the difficulty in regulating the discussion and outline of the task as I could not be there to deliver it due to timetable pressure, as well as a desire not to overstep ethical boundaries. The class chosen was a year 9 class and 17 students completed both the pre and post task questionnaires and were willing to have their answers analysed.

Instruments

This is a small-scale evaluative study employing mixed methodologies (Cohen et al 2017), incorporating an interview (qualitative research), and online questionnaires (both qualitative and quantitative research) (Cohen et al 2017). The aim was to employ a range of methods to allow

triangulation of data gathered and add accuracy to the study. The intentions of the instruments are shown in the table below.

Instrument	RQ Targeted	Purpose
Student First Questionnaire	RQ2	Aim: to ascertain a base level of knowledge about a topic in order to prove whether knowledge increased/improved and was powerful. Q1-6 attempt to ascertain pupil's knowledge of energy use around and the issues surrounding populations' access to it having not studied it before.
Task Completion	RQ2	Aim: To encourage students to make connections using ArcGIS which could be ascribed to PK.
Student Second Questionnaire	RQ1 + RQ2	Aim: To encourage reflection on the task and to consider whether pupil's knowledge improved and could be seen as powerful. Q1-6 same as previous, in an attempt to see what knowledge had been gained through completion of the task. Q7 to ascertain pupils' views of how easy to use ArcGIS software was.
Teachers interview	RQ1	Aim: to discover the ease of implementation of GIS and its impact on the pupil's knowledge. Beginning questions focused on the task and its implementation. Questions then moved on to a wider discussion around GIS use by other teachers and nationally. Questions were open to allow broad discussion and for Teacher A's opinions to come to the fore.

Table 4 – A Summary of instruments used and justification.

Completion of the questionnaire did not take long and was incorporated without difficulty into the intervention. Robson (2018) explains that with forethought, analysis can be routinized and it can generate satisfying data after questionnaires. Another benefit of using questionnaires was that all

pupils could be involved whilst feeling less pressure from the power dynamic than they would have through interview. The models chosen were structured questionnaires with a Likert question (Wilkinson & Birmingham 2003; Cohen et al 2017), the design tried to make the questions more direct to prevent pupils drifting off topic whilst allowing flexibility for a range of answers. Further flexibility was introduced by not putting a word limit on the answers and thus making them open-ended (Cohen et al 2017). I am aware of the difficulty this will present when coming to analyse and interpret the results. To avoid clustering of responses (Cohen et al 2017), I elected to force questionnaire choices by removing middle values (e.g. neither agree/disagree); I am, however, aware that consequently the results divergence will be enhanced (ibid). It was hoped that this would also limit the Hawthorne effect; pupils would feel free to give their honest opinion and not that which they believed I wanted to hear. There was no way around this pitfall, rather reducing it as much as possible was key.

Three broad styles of conducting interviews commonly used are informal interviews, semi-structured interviews and structured interviews (Robson 2018). A semi-structured interview was seen to be the most appropriate in this instance as the interviewer has thought in advance about the main areas he/she wishes to cover whilst free to vary the order or wording of the questions (ibid). If an interviewee covers a new area in response to a question, the interviewer keeps the flow going by asking relevant questions on his list of topics. I used the interview guide approach (Cohen et al 2017) in order to maintain a flexible style and maintain structure. This would be beneficial to help the balance of power and cede some control to the interviewee (Cohen et al 2017). A more systematic format might have yielded more quantifiable analysis but would limit interaction and would impinge the freedom of the discussion. In practice, many interviews in small-scale evaluations are likely to be semi-structured (Robson 2018), the flexibility in delivery of this type of interview sits well with the requirements of having a small number of interviews (in this case one) and was chosen because of the relationship already in place with the colleague.

Limitations

The overriding limitation of the intervention, as already inferred, is that of scale. Coronavirus limited the time I was able to spend conducting research and communicating with participants due to distance learning. It is hoped that the condensing of the task and the research methodology chosen do not reduce validity, rather just the scope of conclusions. As explained, the mixed method approach with results triangulation attempts to provide validity, however, some literature disagrees. Patton (1980) suggests that triangulation using multiple methods does not ensure consistency; Fielding and Fielding (1986) concur, outlining that methodological triangulation does not necessarily reduce bias nor improve validity.

Similarly, the bulk of data for this investigation is from qualitative sources which brings its own limitations. Using the 'human instrument' brings bias (Merriam and Tisdell 2016) when it is the main method of data collection, however Lather and St Pierre (2013) hold a different view, that in a postmodernist approach both researcher and participants' views are made visible. It would be impossible to analyse the viewpoints of participants without some degree of contention – for this reason all possible steps were taken to allow pupils to answer freely and openly. A similar limitation with the scale of the intervention is that only one interview was conducted. It would have been, however, supercilious to assume that further members of staff would have the necessary time or willingness to discuss GIS. This of course limited the amount of time spent conducting interviews; Robson (2004), however, argues that these limits focus the mind to keep the project on task. An issue with semi-structured interviews is that at times they fail to provide space for the interviewee to fully outline their opinion (Savin-Baden and Major, 2013). Furthermore, they are at the mercy of the quality of the questions. I designed the framework of the interview with open-ended questions in order to foster further discussion.

Data Analysis and Interpretation

There are no defined or agreed definite strategies for coding qualitative data (Lichtman 2013). Questionnaire responses were codified and tabulated for ease of comparison. Pupil answers showing a direct improvement in understanding of the question were highlighted allowing a qualitative analysis to take place to ascertain whether pupils made visible improvements in knowledge to facilitate comparison. An assessment as to whether there was an improvement in knowledge, and whether this knowledge was powerful could then take place. Data for the final pupil question was displayed using graphical analysis to quickly convey their responses as one answer.

The interview response was codified and categorised into different themes reflecting different areas of discussion, areas within the transcript were digitally highlighted with different colours in order to identify the main themes of a) time b) training c) TPACK d) other. Rabiee (2004) suggests this is a suitable method when dealing with lengthy transcripts as it aids the researcher in making sense of large amounts of information.

Findings and Discussion

The following sections present the findings in light of the relevant literature. The two respective RQ's form the basis for two sections.

1. What challenges are there to implementing GIS in the geography curriculum? (RQ1)

Finding 1 – The task created was very easy to implement.

The task design was simple; thus, it is pleasing to note that teacher A implemented it without any issues or concern. Various literature outlines the issues that could arise when using GIS to teach, but the main two come down to time and its place in the curriculum (Bednarz 2004). It was with this in mind that the initial interview questions focused around necessary training and time taken for implementation of such tasks. Although the intervention related to a specific task, the nature of a semi-structured interview meant the later discussion took in the issue of GIS in Geography education in a wider sense as well. Time for preparation is one of the main issues with any 'new' technology or policy in education. An important consideration, which didn't feature as highly in the literature was the acknowledgement from teacher A of the privileged circumstances our school sits in.

“Yes, I did find it easy (to implement), but we are in a privileged position that our students do have devices that allow them to do that within the classroom”

The above quote identifies that time in this instance wasn't seen as the main hurdle, but the intervention was only achieved because all pupils had access to personal devices. This differs to Kerski's (2003) main findings when questioning 342 teachers who rated the lack of time to develop GIS-based lesson plans as the main impediment to implementation. The complexity of the software followed in second place with too little technical support for training ranked third. Using a pre-planned lesson for the intervention removed the risk of their first point. The year of this study also negates the second point as so much has changed in the intervening period; ArcGIS is open and there are large amounts of free to use resources online along with helpful videos and tutorials on the ESRI website. At the same time, exacerbated in this most unique of educational periods, the success of basic lessons relies very much on pupils having access to individual computers – a factor not a guaranteed in the maintained sector. Other than time, much discussion has centred around the amount of training teachers have or should receive in GIS. Understanding the technology being used is the essence of the idea of TPACK (Koehler et al, 2013) and why many practitioners fall at the first hurdle. The below quote sums up Teacher A's thoughts and the discussion about this concern:

“And I can see why it might put people off, if you're not using the system a lot all the time and particularly seeing computer software do different things. I had some students whose computers look different to mine on the board. So that could make some teachers feel uncomfortable, but I love technology. So, I think it's really important.”

The final comment about loving technology stands out, as teacher A would thus be more motivated and interested in implementing such technology. Another teacher would see the lack of training and challenges of new technology to be a big barrier in improving pedagogy. This discussion fits succinctly with Wheeler, Gordon-Brown, Peterson, and Ward (2010) who asked 193 Australian teachers to select three main impediments to GIS use. “Lack of teacher GIS knowledge/education” received by far the most indications. “Not enough time for teachers to develop new GIS based Geography” second and “Difficulties in booking the necessary computer labs for GIS lessons” third. Web based GIS potentially

solves the third issue (if pupils have personal devices), thus the other two remain the biggest obstacles. In response to a discussion about how likely they would be to create and input their own GIS activities into lessons, or whether the whole lesson would need to be GIS focused, teacher A explained:

“I would say I'm still at that stage where I feel like I have to have a full lesson”

They went on to discuss previous sequences of lessons where GIS has been used in order to progress in a topic:

“So, when I did five lessons of resources before, I would say that took me about eight hours, but I mean, as you know, I spend ages building resources so it's one thing I find pleasurable. I don't think it's a time thing. I think it's 'I'm not feeling as confident with this technology thing.’”

Again, there is an admission of intrinsic motivation being a key factor in the preparation of resources. If a teacher were not to find the creation of resources ‘pleasurable’ they are unlikely to put 8 hours of time into creating resources for just 5 lessons. I think most teachers would consider this unnecessary and so the need to put energy and time into learning a new pedagogical skill became a key discussion point. Perhaps teacher A's newness to the profession has given her a different opinion of GIS as she never experienced previous versions of the software. As literature and personal experience suggests, hopefully the move to Web based and open source GIS information is making some of these concerns a thing of the past. Fargher (2018, p. 111) explains: “For teachers using geospatial data in schools this has been a revolutionary step forward as time spent grappling with the more complex techniques associated with GIS has largely become a thing of the past”.

The confidence of teacher's use of the technology was also a key discussion point, highlighting that a TPACK framework for training should be investigated further if it is to be integrated more into Geography lessons in the UK. This idea aligns with Oda et al (2020) who concluded their own investigation into the potential of the TPACK framework thus: “Participating teachers positively evaluated their ability to gain knowledge about how TK would interact with PK and CK for meaningful integration and articulated how they would integrate this technology with a pedagogical approach. Overall, they positively evaluated our professional development and regarded it as a useful program for initiating instruction with GIS.” (Oda, Herman and Hasan 2020, p. 51). I hadn't expected the discussion to delve so deep into this area but allowing the interviewee to open up was very much important to valid results. Teacher A went on to explain:

“I feel like the other teachers mock me for liking using ArcGIS, I feel like I'm really confused, like, this is an amazing technology that the kids love using. And it feels like they (other staff) have gone the opposite way like they're rebelling so they refuse to use it. I don't really understand. People say I don't have time to learn. Like, what if I turned around and said that about like behaviour management or like exam practice, but that wouldn't be acceptable. So, I don't really understand how it's acceptable (to not even try using GIS).”

Thus, the opinion of at least this practitioner is that not only is GIS easy to implement but staff training and integration into the curriculum should be mandated, tallying with the findings of Hohnle, Schubert and Uphues in Germany (2013). Such an emotional response was also a revelation of the interview process; although I do not have such experiences to draw on, I would agree that GIS skills are becoming more important in the wider world and more necessary to learn for school leavers. In this sense, there surely must be a call for thorough GIS expertise to become part of the training that Geography teacher trainees undertake. The system cannot rely on a generation of new recruits however, as Hohnle et al discovered when analysing the opinions of German teachers use of GIS “Unfortunately, the hope that these constraints are eliminated automatically by an upcoming technophile generation of young teachers cannot be supported by the results” (Hohnle, Schubert and Uphues 2013, p. 238). That they

discovered age has little significant impact on GIS use points towards the necessity for training to be more freely accessible. Although few would hold GIS in the esteem mentioned above (e.g. compared to behaviour management), there will be many practitioners who agree with its newfound importance in the geography classroom. It is also clear that the pupils found the task easy to understand and complete, further enhancing the claims set out above.

Finding 2 – Pupils enjoyed using GIS as part of Geography Lessons.

Eigbor and Foster (2019) explain that “A limited number of studies have examined the impact of GIS on student engagement, learning, and performance in K–12 classrooms (Fitchett and Good 2012; Goldstein and Alibrandi 2013; Perkins, Hazelton, Erickson, and Allan 2010; Songer 2007)” (Eigbor and Foster, 2019, p. 52). That being so, the triangulation of evidence showed quite convincingly that the majority of those participants involved thought the intervention was worthwhile, enjoyable and would like to use it again. This builds on Kerski (2003) who saw that “GIS increased student motivation for geography, altered communication patterns with fellow students and with teachers, stimulated students who learn visually, and reached students who are not traditional learners” (p.134). Whilst we have already seen the somewhat partisan opinions of teacher A on the benefits of GIS but they also had useful input concerning their opinions on the perception that pupils like using it:

“When I give them a choice programme that they can use or way to display information, a large proportion of the pick ArcGIS story maps to display that.”

Although ‘story maps’ are a slightly different function to the layered map task in the intervention, the ArcGIS programme is the same host and this evidence was seen to replicate Eigbor and Fosters (2019, p. 61) conclusions that “students believed that Story Maps were more engaging than worksheets because they could access a variety of information found on the different map layers”. Teacher A also raised an important point about pupil motivation however:

“Like, maybe I'm more enthusiastic. When they don't see the enthusiasm of the teacher they're not going to do it. Unless someone says, Oh, that's amazing (!), they won't be as interested.”

In this sense Teacher A is explaining that they appreciate the integral nature of feedback as part of pupil engagement and thus having an enthusiastic teacher leading the GIS session would be in some way infectious, passing on the enthusiasm and excitement to them. This is something I have observed in my own practice. In the same vein, the pupil questionnaire led to very similar results as the below graph displays.

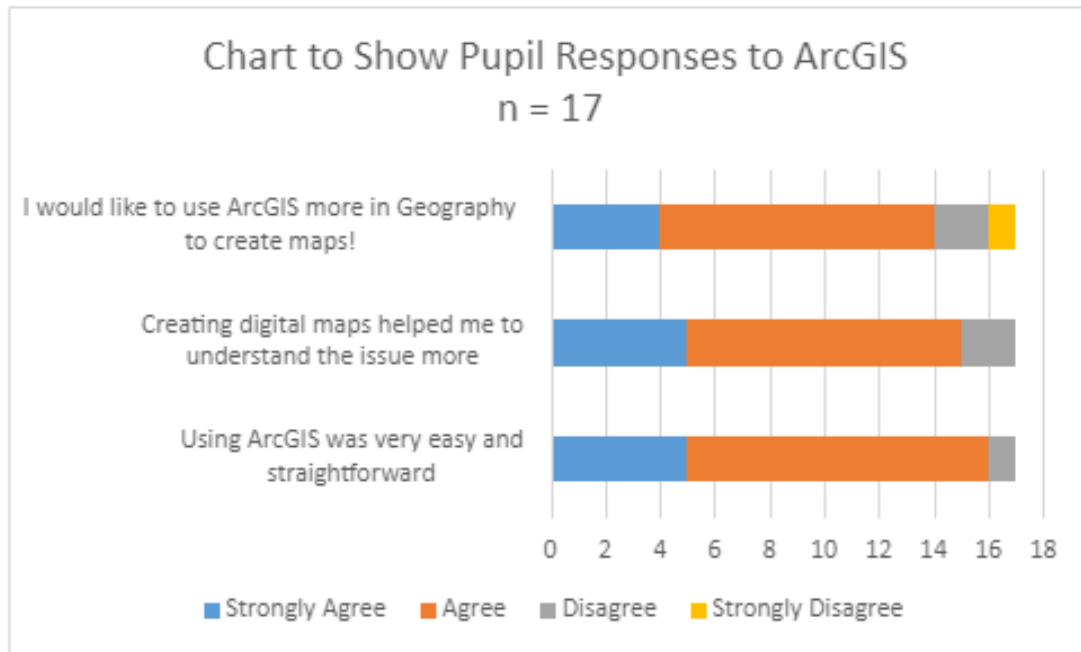


Figure 1 – A Graph to show responses of pupils to the final question in the questionnaire.

Eigbor and Foster (2019) assert the idea that modern pupils want to express themselves using technology and as such GIS tasks should lead to positive returns in pupil satisfaction. Whilst very simplistic and on a small scale, this brief questionnaire shows that 14/17 (or 82%) of pupils answered that they would like to use the programme again to make maps in a similar manner. An even higher response (15/17; 88%) concluded they had made progress in their understanding of the energy issue at hand. These results parallel the research conducted by Perking, Hazelton, Erickson, and Allan (2010) who describe that a placed-based approach was more attractive to students because they learn how to speak spatially, ask spatially, and perform spatial analysis. Further still, only one pupil admitted that they had found the task or the programme difficult to use. This figure is not necessarily reliable, as even with the preparation outlined earlier, many of the pupils may have simply responded with what they thought I wanted. These answers do not necessarily match the question answers, or work produced, which show some basic errors and a lack of understanding of the content. It is, however, a very positive result and enough to warrant further investigation. The amount of GIS tasks and the nature of those lessons will be important factors in pupil’s decision making here, but for the task created and in hand one can certainly see there was enjoyment and engagement.

Finding 3 – Pupils produced good quality work and thus gained other skills in the process.

As previously listed, there is a large body of literature which explains the various skills GIS can engender in pupils. Whilst this isn’t the place to go deeper into explanation, Hong (2016, p. 323) provides a succinct list: “Previous research has found that GIS technologies are helpful to develop students’ spatial thinking, problem-solving and critical thinking skills; to improve their learning; and to provide an inquiry-based and constructivist learning environment (Baker, 2005; Baker, Palmer, & Kerski, 2009; Demirci, 2008; Kerski, 2003; Kerski, Demirci, & Milson, 2013; National Research Council, 2006; Riihelä & Mäki, 2015)”. Although the ‘quality’ of a piece of work is a very subjective matter, there is enough evidence to show that pupils produced work that answered the brief during the intervention. The following are examples of maps produced by pupils which show the task was completed well.

The figure originally presented here cannot be made freely available via ORA because of copyright.

Figures 2, 3 and 4 – Example work produced by pupils.

Esri, HERE, FAO, NOAA | Esri | Natural Earth, U.S. Energy Information Administration (June 2016)

The figure originally presented here cannot be made freely available via ORA because of copyright.

Esri, HERE, FAO, NOAA | Esri | Natural Earth, U.S. Energy Information Administration (June 2016)

The figure originally presented here cannot be made freely available via ORA because of copyright.

Esri, HERE, Garmin, FAO, NOAA | Esri | Natural Earth, U.S. Energy Information Administration (June 2016)

At the same time, we can look to the questionnaire answers (detailed more thoroughly in the next section; see appendix) to assert that learning took place during the lesson. Most pupils finished the lesson with a greater understanding of the topic than when they began – thus the GIS task was responsible for an improvement in understanding of the topic. Teacher A saw a similar benefit:

“I think when they use the layering, I think it's where you start to see where it really adds value”

Certainly, the task represented a different set of skills to those which pupils would usually use, but the interpretation of maps is something they will have considered before. During the interview, we also discussed potential skills which would be gained from an increase in GIS use. Coming to the profession relatively recently gave teacher A, a rather unique viewpoint in this area:

“They'll be going into the workplace and with my hat on having worked in corporate NGOs and councils and all sorts of things for decades before coming into teaching, I know the world that they're going into, you know what I mean, like my mindset is slightly different. And I feel like we don't prepare them for the digital world, like they're not going to be using pen and paper the moment they turn up for their job, like it just won't happen. And I always ask them, like, you know, you just need to learn this resilience. If I throw a programme at you, you need to just go ‘I really need to give this a go’, rather than just giving up and sticking to what I know.”

Regular investigations have assessed whether GIS use can increase spatial analysis skills (see quote from Hong above), but here we see the potential for such activities to provide other skills and benefits. It is certainly true that digital mapping is becoming more prevalent in the world and we are all using it more often, sometimes without acknowledgment. This viewpoint is not new in the world of GIS, Bednarz (2004) made such an idea one of the three most important reasons for introducing more GIS named the workplace justification – GIS is an essential skill that makes pupils more employable. Here then we have potential evidence that not only do pupils produce good academic work, but they are gaining a wide variety of skills, not only resilience (mentioned above) but others; when reflecting on the task, teacher A also explained:

“I didn't teach them how to do it, they taught each other. One learnt and then taught the other one, and they will just share knowledge, and I suppose that comes down to being a totally independent learner, some more than others.”

This viewpoint again mirrors that of Eigbor and Foster (2019, p. 61), who (although focusing on Story Maps) evidenced the peer collaboration that GIS work creates; “Although the participants initially found Story Maps challenging, they eventually endured through peer collaboration”. Potentially then more evidence for the variety of skills to be gained through completion of such tasks. The interview discussion did then veer onto the validity of our thoughts and how certain we could be that GIS is actually responsible, or whether such skills could equally be gained from another activity or approach. Teacher A made a distinction between the use of ArcGIS and some other ideas seen as gimmicks:

“It's not like trying to teach the kids about the different layers of the earth by baking a cake, where whilst they've learned how to bake a cake, they're not really learning about the actual content we want to learn about. It could be interesting for all kids learning about digital platforms using ArcGIS but, is that what they're learning? Or actually are they learning typography?”

Walshe (2018) has similar worries, explaining that there is a danger of reducing the purpose of geography lessons to learning a set of transferable skills, which results in a focus on the technology of GIS, rather than something inherently geographic. Further investigation is needed to challenge some

of the above concerns. The debate about what constitutes learning is too large to delve into here, but GIS's potential is certainly an area which warrants debate, especially in Geography. Whilst there is evidence to suggest pupil's digital literacy would be improved through greater GIS use, there may be other ways of introducing these skills too. It is thus my opinion that the ArcGIS programme is very powerful and that the more pupils and educators use it and become accustomed to it, the greater the benefits will be. Indeed, Fargher (2018, p. 7) explained "The use of geospatial information in school geography has entered a new era, one in which the promise of high-quality mapping, spatial analysis and geovisualisation to support geographical learning via webGIS is more accessible than ever before".

2. Does using GIS provide evidence of access to 'Powerful Knowledge'? (RQ2)

Finding 4 – The task produced evidence access of PK.

As previously discussed, the framework for analysing the potential creation of PK was based on Walshe's (2018) explained categories (From Maude 2016) of Powerful Geographical Knowledge, namely:

1. Knowledge that provides students with 'new ways of thinking about the world'
2. Knowledge that gives students some power over their own geographical knowledge.
3. Knowledge of the world.

A full table containing responses from each pupil can be seen in the appendix but there is evidence from the answers to different questions in the questionnaire that fulfil the ideals set out by Walshe (2018). The above ideas will be analysed sequentially for clarity.

Maude (2016) described Type 1 knowledge as that using meta-concepts such as place, space or environment. The greatest evidence for this came from the questions which elicited longer answers from participants, which allowed pupils to visibly improve on their baseline understanding and to increase knowledge. Whilst not all students made discernible improvements in knowledge, 60% (10/17) gave answers that contained an improved understanding of the third question: "What is the relationship between population density and energy use per capita, in different parts of the world?" In the pre-task questionnaire, this area was generally answered poorly with only a couple of pupils showing technically correct answers – unsurprising considering they had not studied the issue before. Most assumed that an increased population density led to an increased energy consumption per capita, thus confusing density with total population. The main theme that pupils picked up on through the task was understanding that development had a much greater impact on energy use than the population. That pupils made this link without prompting or assistance from the teacher means we can be confident that it was the task itself which made them think differently. The below table highlights all pupils whose answers showed improvement and thus a potential display of access to powerful knowledge (pupil work has been left unaltered).

Pre-Task Answers	Post Task Answers
What is the relationship between population density and energy use per capita, in different parts of the world?	
the higher the population density the higher the energy use per capita	more densely populated areas like india dont always use more energy. normally more developed countries like the us use more energy.
the more people in an area = a higher energy use per capita	In Africa, even though the population density is very high, the energy consumption is still low and the circle is roughly the same size as the UK. In places like America, the population density is low and so is the energy like i would assume
the denser the population the more energy that is going to be used per capita	the more developed countries use more energy than the less developed countries. The population density in India is very high however as its not a developed country it uses a lot less energy than England (a developed country) which is also has a high population density.
the higher the population density the higher the energy use per capita becomes	the higher the energy usage in an area, the higher the population density will be as more people are using energy and so it will therefore be higher. there are very few countries that have a high population density but low energy consumption however there are some countries that have a low population density and a high energy consumption
The population density usually increases with energy use per capita.	Population density usually increases with energy use per capita depending on the level of development.
in a developing place in the world, the population density is larger than the energy use per capita	In poorer areas of the world, there is a higher population density than energy use per capita, and in wealthier parts of the world, the energy density is higher than the population density.
The energy use per capita depends on the population density. For example, if the population of a country is big their energy use will be up. Whereas if a countries population is small their energy use will not be much.	the population does not depend on the energy use per capita. A country might have a low population density but their energy sue per capita may be very high. Or India for example, has a very high population density but it's energy use per capita is not that high. This is due to different reasons, such as, the development level of a country their income etc..
The more dense a place, usually the more energy used, as there are more people that require energy to live. however if this country was a less developed country with a lack of resources and therefore access to energy it might not use as much energy per capita.	In developed countries or cities energy usage usually increases as the population density is larger, however in less developed countries sometimes the population density can be very large however with small amounts of energy usage.
The energy use per capita firmly depends on the population of the area because the bigger the population is, the more energy it requires to provide for all the people.	The bigger the population is, the more energy is required. However, it also depends on the amount of research or development occurring in the area eg. Iceland has a very small population but masses of energy consumption.

Table 5 – Selected pupils answers showing potential evidence of powerful knowledge acquisition.

I would therefore argue that completing the task made these pupils more aware of the causes of energy consumption in different areas of the world (thus new ways of thinking about places). In some instances, pupils used specific country examples in their answers, showing that the creation of digital maps improved subject knowledge whilst making them think differently about the world around them. For example: “Or India for example, has a very high population density but its energy use per capita is not that high”. In all of the selected answers above there is evidence of pupils applying the knowledge that they have gained from the task to the situation being presented. The task itself did not make any distinction between countries that are or are not developed, and it was surprising to see so many pupils make the connection themselves, bringing prior knowledge about development levels into a discussion of energy use – one could argue this is evidence of PK being accessed.

In a similar manner, the 4th question: “Can you think of any countries which have low population densities and high energy use per capita? Why would this be?” was specifically designed to elicit pupil understanding countries in different areas – Maude’s place, space or environment (2016). Although slightly fewer pupils showed visible changes in knowledge (9/17), there was again enough evidence to suggest that potential PK had been accessed. The table below shows the responses of pupils to both sets of questions:

Pre-Task Answers	Post Task Answers
Can you think of any countries which have low population densities and high energy use per capita? Why would this be?	
Qatar because they are very developed so use lot of energy but there is very little people in the country	United States Virgin Islands have a high energy consumption but most of the country is rural or slightly urban. I have no idea why this is the case.
Qatar because their technology is very developed and therefore needs more energy.	Australia has a low population density but high energy use per capita, this could be because it's very developed and needs more energy for the technology but also because it will need a lot of energy for air conditioning.
this could be because the majority of people who live in this country could be very wealthy so have bigger houses therefore need more energy to keep the house warm etc.	Iceland have a high energy consumption but a low population this could be, that the majority of people there are wealthy so have bigger houses which they want to keep warm, since it is a very cold place there will be lots of people wanting to have a warm house.
Qatar is not very populated but use lots of energy this is because it is very well developed so the country can run the amount of energy that is needed	qatar because it makes lots of money by selling its energy and it also does not have many people living in it so it is a very Ritchies country so it can afore lots of energy
Well, they might use that energy for certain infrastructures which take up lots of energy instead of lots of people	Greenland, they have a small population density but consume and produce lots of energy

For example, Qatar has a low population density but has a high energy use per capita, this is because Qatar is a very rich country and they have a lot of energy security.	The majority of Australia does not have a high population density but their energy use per capita is high. This is because Australia is a developed country and is a rich country.
Possibly Qatar as they use a lot of energy due to their country being very wealthy and developed. However they aren't necessarily a big country with that large a population, therefore the density is lower.	Norway consumes quite a lot of energy, however the country has quite low population density. This might be due to the country being developed and having lots of resources.
I can't think of any countries however the reason for lots of energy use is that the country may be developing and therefore requires energy to evolve and develop its infrastructure or technology.	Iceland and the Caribbean use a lot of energy as seen in the 2016 arc GIS map, this probably because most factories, industries are developed and used in that area.

Table 6 – Selected answers from questions showing potential powerful knowledge acquisition.

Once again, we see the initial question highlighted a common misconception by students (see appendix), with those highlighted above mostly using Qatar as an example of a country with high energy use. This could have been because of a previous topic highlighting Qatar in development terms as having a high GDP due to energy production. As can be seen, all but one of the pupils above change the example they use, with Australia, Iceland, Norway and other smaller islands coming up as countries with small population density, but high energy consumption. Many then go on to try and explain this using the limited information at their disposal. Here again we see that the simple information contained on the two map layers they were asked to create has led to an improved knowledge of the world. This corresponds with Fitchett and Good's (2012) assertion that the use of GIS applications provides avenues for pupils to explore from a spatial perspective while enabling them to take ownership of their learning. There are, however, anomalies in the information above with Greenland and the United States Virgin Islands whose values would be impacted by information from their territorial powers (Denmark and the USA). This highlights that although knowledge is being created, it will take further work to ensure that knowledge is correct and useable in the future (e.g. for assessments). What is evident is that pupils are very easily able to interpret the maps they have created, and use their own knowledge in order to make sense of the world, or even change their world view. The teacher as expert is still required to monitor progress and understanding. Thus, in order to successfully integrate GIS, teachers are the key component (Ertmer, 2005; Hughes, 2005; Wallace, 2004). This understanding is a key facet of the GeoCapabilities project mentioned earlier. It is underpinned by the belief that knowledge development in schools should be led by subject specialists who are best placed to provide young people with the highest quality geography education (Fargher 2018). Healy and Walshe (2020) went a step further by using real world GIS experts to aid pupils and found that they seem to facilitate students' engagement with powerful geographical knowledge (as defined by Maude, 2018) through the activities and interactions that unfold in the classroom.

The above also provide examples of pupils having control or 'power' over their own geographical knowledge. Indeed, there are several examples of pupils using prior understanding or knowledge of countries or areas to build their understanding during the task. Although it is appreciated that this is a skill in itself, and that not all pupils made these links, to see some evidence points to potential for further study. The strongest evidence, however, comes in the way that the ArcGIS task allows pupils to create their own design and answer questions using whichever examples they see fit. Two good examples in the table above are that of Australia and Iceland and their energy use. Pupil's prior

understanding of the relative climates in these areas allow them to correctly make connections such as:

“since it is a very cold place there will be lots of people wanting to have a warm house” (Iceland) and “needs more energy for the technology but also because it will need a lot of energy for air conditioning” (Australia).

The task has allowed these pupils to control their own learning and to bridge the gap between topics – somewhat matching the ideals of PK through improved subject knowledge (Maude 2016). Also, the various connections with the development level of countries explain similar links and allow pupils to express their prior geographical knowledge. In some instances, this change is very subtle but does display a real insight into the effectiveness of such a task:

The population density usually increases with energy use per capita.	Population density usually increases with energy use per capita depending on the level of development.
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The above example has only a few words difference but is potentially the best example of improved understanding of the issues presented by the task. Using ArcGIS allowed the pupil to gain recognition that their first assumption was not incorrect, rather it needed expanding.

The first two questions showed that pupils had basic subject knowledge which could be improved to gain control of their own understanding. Although only simple definitions, it is clear that most pupils made some small adjustments to their answers in order to be more accurate.

Pre-Task Answers	Post Task Answers
Can you define energy use per capita?	
how much energy is used per capital city	how much energy is used per person in a specific place
The total population energy consumption	average power use for each person
The energy consumed in a country or certain place	energy consumed per person in a country

Table 7 – Selected pupils answers showing potential powerful knowledge acquisition.

Although only 3/17 responses show this improvement in basic geographical knowledge, many of the other respondents had the correct definitions first time, thus little improvement could be made. Healy and Walshe, who were similarly investigating GIS and PK, had concerns about the superficiality of pupil reflections in that they lack the deeper engagement to fully explore the roots of geographical knowledge encountered (2020). Although this level of reflection is potentially unrealistic for year 9 students, there is definite scope for further investigation here too.

Through Geography, one would hope it would be difficult to teach whilst not producing increased or improved ‘knowledge of the world’ (Maude 2016). The term is so broad that much of what is taught could be classified as evidencing PK in this sense. Roberts (2014) however disagrees with this assumption: “In spite of geography having ways of studying the world that are potentially powerful in assisting understanding, the knowledge produced by human geographers, in particular, does not have the characteristics of powerful knowledge identified by Young” (p. 205). Although not writing

specifically about GIS, she makes a valid point about the difficulty of distinguishing between every day knowledge and academic knowledge. In order to try and provide evidence from this task, one can see various situations where pupils gained knowledge of specific places which they did not know about before. As previously mentioned, many pupils use examples in the post-task questionnaire taken directly from the maps they have created. Indeed, the longer middle questions provide evidence of this for nearly all pupils. We can also look to the work that pupils created as simple indications that their knowledge of the world increased. Whilst pupils begun to grasp the “skills needed to deal with the complexity of geographical knowledge” (Roberts, 2017, p. 8), further work needs to be completed to ensure pupils are able to analyse and explain as an integrated part of a geographical project. Returning to Healy and Walshe (2020), we see similar evidence “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” (p. 193).

Another way of interpreting knowledge of the world might be to analyse the understanding that pupils have of the most important global issues of our time. The final two questions were concerned directly with allowing pupils to think about the future of energy production and consumption globally, considering the impact on Climate Change. The pupil answers in these areas show little change between the pre and post questionnaires. One could interpret this in different ways – the fact that the Climate Change issue is so regularly in the global news cycle and on other media mean that pupils have a good assessment of the main causes and solutions. Pupil answers have much discussion of fossil fuel use and increasing population densities leading to increasing emissions. Similarly, the vast majority of responses mention that renewable energy sources are necessary for a reduction of the problem. Whilst the creation of the task didn’t include statistics from various years, the hope was that pupils would be able to extrapolate that those developing countries would continue to grow and increase the burden put on the climate. Whilst no evidence of this expected outcome came to light, we can see some examples where pupil knowledge of the world was enhanced through the creation of the maps and an understanding of the different consumption rates around the world.

Pre-Task Answers	Post Task Answers
What impacts do you think increasing population densities around the world will have on climate change?	
Demand for air conditioning in arid countries will increase, which will fuel global warming.	It will increase the demand in energy. And to produce energy you need (non) renewable energy. For example demand for coal will increase, polluting the air, increase CO2 levels and fuelling global warming
the higher the population density, the higher the energy use becomes- more coal, gas etc will need to be produced and during this process co2 is released and this increases the rate of climate change to occur sooner. so it is an overall bad impact if population densities increase	by increasing population density, more pollution will be created and climate change will occur sooner. there will be a higher demand for energy and so the process of obtaining that energy will have to increase causing more co2 emissions which will have a bigger negative impact on climate change

Table 8 – Selected pupils answers showing knowledge of the world around them.

Although a very small sample, there is validity of the idea that pupil’s knowledge of the world has improved. Through a short task, both pupils above have used the information presented to them to build an improved and more accurate viewpoint about development and climate change. Although

their original subject knowledge still stands, their understanding of the world and ability to apply that knowledge has increased.

Finding 5 – The task had no evidencable impact on two pupils and limited PK was seen accessed by others.

Inevitably, with such a small sample both successes and failures will be exaggerated. Whilst some pupils took to the task with ease and showed clear evidence of understanding, there were two pupils who seemed to take no new knowledge from the task content, nor to use the information they created to answer the questions. The table below (Table 9) displays their answers to the extended answer questions. For these pupils, there was potentially a lack of motivation or interest. Roberts (2014) when discussing PK related that school knowledge remains inert if students are not motivated to learn it and if they cannot make sense of it in some way for themselves. Indeed, she goes on to explain “If students are to gain access to potentially powerful ways of thinking, to think as a geographer thinks, then they have to engage with geographical knowledge” (p. 204). There is then also evidence that for some individuals, the ArcGis programme or task design failed to allow access to PK, or indeed any visible improvement in knowledge whatsoever. In many cases the answers to both questions were simply repeated, in some examples the incorrect knowledge was simply replaced with other, similarly incorrect or vague assertions:

“Oman as it is located by the sea and so it might have less natural resources”.

It is unclear where such information may have come from as no information provided about the level of resources in countries. There was also a common misconception across many of the participants that population density and total population were the same or intrinsically linked, again the two examples below are good evidence of this. Although some pupils were able to understand that development was more important in respect to energy consumption, without explicit information to some pupils could not or did not make this link. At the same time, there may have been confusion surrounding the task and the completion of it as there was no teacher input unless direct questions were asked. Whilst the two below pupils showed no evidence of learning, others struggled with some aspects which limits evidence of access to PK. Thus, some pupils would need further training in either the use of the ArcGIS programme, or the skills of interpretation of the digital map produced.

Pre Task Answers	Post Task Answers	Pre Task Answers	Post Task Answers	Pre Task Answers	Post Task Answers	Pre Task Answers	Post Task Answers
What is the relationship between population density and energy use per capita, in different parts of the world?	Column3	Can you think of any countries which have low population densities and high energy use per capita? Why would this be?	Column4	What impacts do you think increasing population densities around the world will have on climate change?	Column5	What do you think the future of energy supply around the world is?	Column6
the more people in an area (the population density)the most likely the higher the energy use per capita	the more people the most likely the more energy used	because they are wealthier than other country's is that they have more extreme weather so they need more warmth, cold or light.	because their demand for energy is higher.	the water levels will rise so anyone who lives on the coast will effectively get their houses flooded or destroyed.	there would be higher water levels therefore peoples houses would be flooded.	more people are trying to use less energy and conserve it as well as trying to use more renewable energy resources.	they will soon run out of energy and we need to conserve it.
the more dense the population is the more likely that it will use more energy	that normally the more dense a country is the more amount of energy the place will use	Im not surest it could be because they have less natural resources around them or they are still a developing country	Oman as it is located by the sea and so it might have less natural resources.	we are having to use more resources from the natural environment which has meant we are taking away three habitats	that with increasing population it will mean that we will start to use more energy which is harming the environment and the animals that live there	that if we don't change what we are doing then soo we will run out so we need to start use more renewable sources of energy not fossil fuels	That we have to start using more renewable energy as we can't keep on living like we are as soon the whole ecosystems will stop working

Table 9 – Selected pupils answers showing poor quality answers and a lack of knowledge acquisition.

Conclusions

An outcome of the investigation is the recognition of the technological leaps that have been made in the accessibility of GIS, which whilst not a new discovery, runs counter to some of the (older) literature. The excitement of its potential seen in literature has been borne out in practice, indeed, much of the literature now seems outdated as the technologies change so rapidly. Whilst it may still be the case that some teachers are reluctant to incorporate GIS due to the various barriers (e.g. Liu and Zhu 2008), this small study encountered the opposite; teachers were encouraged and motivated by its use. Fargher (2018) came to a similar conclusion: “The removal of most of the historical barriers to GIS use in schools regarding cost, complexity and access has been a real watershed for those teachers now incorporating the use of webGIS in their classrooms” (p. 12). What is well evidenced in the literature and supported by this study is the need for better training and access for teachers who might struggle. These were, however the exact issues raised by Bednarz and Van der Schee (2006) when they recommended “institutionalizing GIS into curricula, making sure that it is aligned with significant general learning goals like graphicacy, critical thinking and citizenship skills, and developing student assessment and teacher reward systems that accommodate GIS” (p. 203). Perhaps the removal of some barriers through webGIS will finally make a difference.

A secondary conclusion is that GIS has many pedagogical benefits for pupils and staff in secondary schools, an idea supposed by Demerci (2008). Throughout this intervention, the use of GIS improved pupils’ understanding of the topic and led to evidence of more powerful knowledge being accessed. What is clear is that the use of GIS brings information to life and gives students the freedom to investigate geographical phenomena and issues themselves. GIS can serve to put pupils in control of their own learning as well as give them a curiosity about the world around them; in this sense, it is very much ‘powerful’. It is my belief that it also provides pupils with the intrinsic motivation needed to further engage with the ‘geography’ of an enquiry. As students become more confident with GIS, focus can be shifted to ensure that developing pedagogical content knowledge becomes a central principle. This would go some way to addressing the barriers posed by Walshe (2018) and ensuring technology can support learning rather than detract from it (Healy and Walshe 2020). Thus, rather than exam boards adding GIS skills to curricular without visible support, or making it a skill to be ticked-off (Walshe 2018), it should be seen as a means to developing geographical thinking and powerful subject based knowledge. This becomes a more sustainable approach as pupils transfer this learning to other areas of geographical study (Healy and Walshe 2020). This research has highlighted the need for GIS to become more integral to geography curricular in the UK and across the world. Even if one doesn’t agree with the fundamentals of PK, the use of GIS engenders some of the fundamental aspects of geographical skill acquisition. This research allies itself with Fargher’s (2018) view that we should look for future use of webGIS (ArcGIS) to enhance geography education embracing technological innovation, but also the creation of powerful disciplinary knowledge.

Limitations

The main limitation and implication of this investigation mimics the global issue that the Coronavirus pandemic brought to education; pupils were not in school and had missed out on months of education. The proposed initial timeline for the investigation had a much more in-depth intervention occurring in January. This was impossible during the lockdown of early 2021, the plan had to be condensed and delayed. This led to less data from pupils being collected and a smaller sample. I am confident, however, that the results gained are still valid. Similarly, the fact that I was working with pupils in my own school, especially those that I teach make the subjectivity of the data questionable. Although, as explained, all possible actions were taken to encourage honesty and freedom of thought from the

participants, there inevitably would have been some power dynamic which affected the results. This is a consequence of “studying in your own backyard” (Creswell, 2016 p. 19).

Implications

The collaborative aspect of this work has not only improved my relationship with those in my department, but has motivated me to work more closely with other teachers when designing resources (not just through GIS). Similarly, to discuss more regularly the main issues surrounding teaching geography and work more closely with others to improve my own pedagogy. The interview opened my eyes to the idea that sharing practice more regularly with other professionals yields great benefit and stimulates good ideas. The next step in this regard will be to encourage other members of the department to use GIS more regularly and to work on reducing the barriers for them to do so. Another interesting direction could involve incorporating mobile technologies, such as smartphones and using programmes such as Esri’s Survey123 to collect data in the field. Similarly, cross-curricular links could be set up, firstly in the humanities, to celebrate the real benefits that the use of GIS can bring in lessons. This work has aided the geography department of my school, not only with more resources, but with increasing numbers of pupils becoming more familiar with the use of the ArcGIS system – something that will advantage them greatly when it comes to employability.

On a more personal level, apart from the obvious ‘upskilling’ of my technical pedagogical knowledge, I feel that I have become a more reflective and collaborative practitioner. I am more comfortable and experienced with the various systems of GIS and how best to implement them in lessons. Having seen first-hand the ease with which pupils have picked up new skills I aim to use GIS more often to increase their world view. My aim at the beginning of this work was to investigate a personal view that GIS is an enjoyable and extremely powerful educational tool. I have always loved and been fascinated by maps – I believe that many children are – and GIS represents an exciting progression on this theme. Whether or not one believes that the knowledge accessed is ‘powerful’, there is definitely a benefit to an increasing understanding of the world, and our place in it.

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Appendices

Appendix 1 – Full pupil questionnaire results.

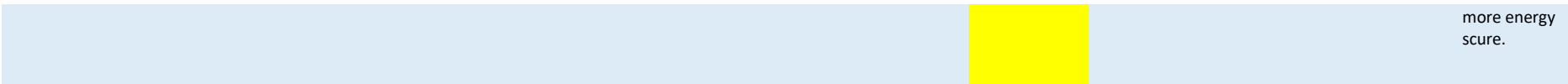
	Pre Task Answers	Post Task Answers	Pre Task Answers	Post Task Answers	Pre Task Answers	Post Task Answers	Pre Task Answers	Post Task Answers	Pre Task Answers	Post Task Answers	Pre Task Answers	Post Task Answers
Number	Can you define energy use per capita?	Column1	Can you define population density?	Column2	What is the relationship between population density and energy use per capita, in different parts of the world?	Column3	Can you think of any countries which have low population densities and high energy use per capita? Why would this be?	Column4	What impacts do you think increasing population densities around the world will have on climate change?	Column5	What do you think the future of energy supply around the world is?	Column6
1	the average energy use per person	the ammount of energy used on average per person	the ammount of people per square meter	the ammount of people per square meter	the higher the popultion density the higher the energy use per capita	more densly populated areas like india dont always use more energy. normally more developed countries like the us use more energy.	uk its a developed country so people use more energy	uk its more advanced so people use more energy than those in poorer countries.	they will use more energy so that means more fossil feuls burnt which is worse for the enviroment	it will increase climate change because as more people are born they will need more energy which normally comes from fossil feuls which are damaging the enviroment.	renewable feuls	renewable

2	The amount of energy used per person on average in a country	The energy consumption per person	The amount of people in a certain area	the amount of people who live in a certain area	the more people in an area = a higher energy use per capita	In Africa, even though the population density is very high, the energy consumption is still low and the circle is roughly the same size as the UK. In places like America, the population density is low and so is the energy like i would assume	Qatar because they are very developed so use lot of energy but there is very little people in the country	United States Virgin Islands have a high energy consumption but most of the country is rural or slightly urban. I have no idea why this is the case.	More population density means more energy use so more emissions from bad sources so more damage to the ozone layer so penguins will die and the climate would change	The more the population density = more energy use per capita so more pollution from non-renewables so more co2 so a damaged ozone layer and higher temps and more water as ice caps melt	Renewable energy sources but mainly tidal, wind and solar	Non-renewables especially solar panels in warm areas, tidal in costal countries and wind in cold but windy places.
3	how much energy is used in a given country or area	the amount of energy used by a certain area or country	the number of people in a certain area	how populated a certain area or country is	the denser the population the more energy that is going to be used per capita	the more developed countries use more energy than the less developed countries. The population density in India is very high however as its not a developed country it uses a lot less energy than England (a developed country) which is also has a high population density.	Qatar because their technology is very developed and therefore needs more energy.	Australia has a low population density but high energy use per capita, this could be because it's very developed and needs more energy for the technology but also because it will need a lot of energy for air conditioning.	The increasing population will mean more energy is needed and therefore more fossil fuels will probably be used to try and supply for everyone.	More energy will be demanded by the population and the fossil fuels will be used as an easy way to get energy in the poorer countries	renewable sources such as solar power and wind power but they need to develop	Renewable sources

4	the average amount of energy a person uses	the amount of energy people use per capita	the number of people per area	the amount of people in one country	the more people in an area (the population density)the most likely the higher the energy use per capita	the more people the most likely the more energy used	because they are wealthier than other country's is that they have more extreme weather so they need more warmth, cold or light.	because their demand for energy is higher.	the water levels will rise so anyone who lives on the coast will effectively get their houses flooded or destroyed.	there would be higher water levels therefore peoples houses would be flooded.	more people are trying to use less energy and conserve it as well as trying to use more renewable energy resources.	they will soon run out of energy and we need to conserve it.
5	energy use per person per capita	Amount of energy used per person per capita	Amount of people per square mile	Amount of people per square mile	Most densely populated areas have high energy usage	The more densely populated an area is, the more energy is used	Iceland. They produce a lot of energy with a population of around 300,000. Energy would be cheap there so people will maximise.	United Arab Emirates. You will find where it is densely populated, energy per capita is high.	Demand for air conditioning in arid countries will increase, which will fuel global warming.	It will increase the demand in energy. And to produce energy you need (non) renewable energy. For example demand for coal will increase, polluting the air, increase CO2 levels and fuelling global warming	Renewable energy	I think renewable energy, for example solar energy. It may not be cheap but in the long run it will save you a lot of money and it does not pollute.

6	how much energy is used per capital city	how much energy is used per person in a specific place	how many people live in a certain area per km squared	how many people live in a certain place, km 2 is a unit	the higher the population density the higher the energy use per capita becomes	the higher the energy usage in an area, the higher the population density will be as more people are using energy and so it will therefore be higher. there are very few countries that have a high population density but low energy consumption however there are some countries that have a low population density and a high energy consumption	could qatar be one? or Iceland ? this could be because they have large supplies of energy in their country and so they are taking advantage of this and using lots of it, exporting etc	NA	the higher the population density, the higher the energy use becomes- more coal, gas etc will need to be produced and during this process co2 is released and this increases the rate of climate change to occur sooner. so it is an overall bad impact if population densities increase	by increasing population density, more pollution will be created and climate change will occur sooner. there will be a higher demand for energy and so the process of obtaining that energy will have to increase causing more co2 emissions which will have a bigger negative impact on climate change	i think countries will be forced to go renewable so either solar, wind, tidal, hydropower etc as they will have no other choice due to climate change	i think countries will have to turn to renewable as due to climate change they won't have a choice and it will be more sustainable for them and their country's future generations
7	the amount of energy being used per state county place	use of energy per capital country	how many people there are in a place	the amountn of the population in an area	to work out how much energy is being used per capital or place or in the population	high density countries use less energy	Qatar as there are anrt a lot of people there but they use a lot of energy	india as it is a poor country	pollution rising and the word will heat up and become more humid causing icebergs to melt.	yes the more energy we use the hotter the ountry will get	we are using more energy but we are now starting ti use more and more renewable energy sources so I think we use little non renewable	countrys are usning more energy

10	Average energy use per person	Amount of energy used per person	amount of people in a certain area.	Amount of people in one area	in a developing place in the world, the population density is larger than the energy use per capita	In poorer areas of the world, there is a higher population density than energy use per capita, and in wealthier parts of the world, the energy density is higher than the population density.	England. This is because there are people who can afford lots of energy, even if there is a small amount of people.	England would have low population density compared to energy use per capita because they can afford lots of energy per household or person even if there isn't a large population	The more increased the population density becomes, the energy per capita increases as well, which means that it will make climate change worse.	The more the population density increases, the more energy will be used. This means that more gases will be let out into the atmosphere.	I think more renewable energy sources will be used, but before this, the non-renewable energy sources will run out.	I think that more non-renewable energy sources will be used until there will be none left, then eventually people will start using renewable energy sources.
11	it id the energy used per person	how much energy is used in a cirton area or country	how populated a country, town or a Citroen area is	how many people a living in an area	the relation ship is how developed the country is and how much energy they use. so if a country was not very populated it would not use lots of energy and that would be the same if it was populated but not well developed	the relationship is that it shows how developed a country is and how some country are developed and wealthier and others are not	Qatar is not very populated but use lots of energy this is because it is very well developed so the country can run the amount of energy that is needed	qatar because it makes lots of money by selling its energy and it also does not have many people living in it so it is a very Ritchies country so it can afore lots of energy	I think that this will make the climate change worse and happen more rapidly because we will have to use more of the things we are using now that are creating solution and climate change	I think that the more populated the world gets the worse the climate change will get this is because we will have to use more of the energy that causes us to burn more and this produces more pollution. so the more people we have the more things we have do do that make the climate change bad.	I think that it will get better because more people will start to use renewable. this will help the earth and it will also mean that we don't ever run out of it	I think that it will get bad for a bit because people will start to run out of things but then it will get good again because people will start to use renewable energy a lot more. this will help with the earth repairing and it will also help to make shore we do not run out of energy and that it is



more energy score.

12

How much energy use there is per area or certain country

A measure of energy efficiency in a country

How many people there are in a certain area or country

Is a measurement of population on a certain area

Well the higher the population the more energy use per capita

Well, the higher the population of an area the more energy is consumed

Well, they might use that energy for certain infrastructures which take up lots of energy instead of lots of people

Greenland, they have a small population density but consume and produce lots of energy

I think that it will have a negative impact on the world and climate change as more people mean more energy and would mean more Fossil Fuel being produced in certain countries and areas around the world which will harm the world.

negative impact on the world as the more people the more energy consumed and in most cases Fuels are chucked out in the atmosphere

I think that the future has to be Renewable Energy as all these Fossil Fuels are going to kill us out if we are not careful so we will have to use energy forms such as wind turbines solar panels and invent more economical way to enhance nuclear power which is happening as we speak.

Renewable Energy as is good for the environment and better than fossil fuels for climate change

<p>13</p> <p>The energy consumed in a country or certain place</p>	<p>energy consumed per person in a country</p>	<p>the Population per place. The population of a certain place</p>	<p>the population of a country</p>	<p>The energy use per capita depends on the population density. For example, if the population of a country is big their energy use will be up. Whereas if a countries population is small their energy use will not be much.</p>	<p>the population does not depend on the energy use per capita. A country might have a low population density but their energy sue per capita may be very high. Or India for example, has a very high population density but it's energy use per capita is not that high. This is due to different reasons, such as, the development level of a country their income etc..</p>	<p>For example, Qatar has a low population density but has a high energy use per capita, this is because Qatar is a very rich country and they have a lot of energy security.</p>	<p>The majority of Australia does not have a high population density but their energy use per capita is high. This is because Australia is a developed country and is a rich country.</p>	<p>As the population increases climate change will grow. This is because people are ruining the climate by throwing waste everywhere and ruining the wildlife. Furthermore, as population increases the world will become more developed which means there will be more factories which effect climate change very negatively.</p>	<p>Increasing population densities will impact climate change negatively.</p>	<p>I'm not quite sure but I'm guessing that energy supply will decrease because the majority of our energy supplies which are non-renewable sources are not going to last forever.</p>	<p>Energy supply around the world is decreasing because fossil fuels are decreasing an sooner or later we will run out of energy. So, people have to be wise now and start being sustainable with energy and turn more to renewable-energy sources.</p>
<p>14</p> <p>the average use of energy across a country</p>	<p>the average amount of energy used per place in a country</p>	<p>the measurement of population per unit area</p>	<p>the amount of people who live in a certain place in a country</p>	<p>the more dense the population is the more likely that it will use more energy</p>	<p>that normally the more dense a country is the more amount of energy the place will use</p>	<p>Im not surest it could be because they have less natural resources around them or they are still a developing country</p>	<p>Oman as it is located by the sea and so it might have less natural resources.</p>	<p>we are having to use more resources from the natural environment which has meant we are taking away three habitats</p>	<p>that with increasing population it will mean that we will start to use more energy which is harming the environment and the</p>	<p>that if we don't change what we are doing then soo we will run out so we need to start use more renewable sources of</p>	<p>That we have to start using more renewable energy as we can't keep on living like we are as soon the whole ecosystems</p>

									animals that live there	energy not fossil fuels	will stop working	
15	The total population energy consumption	average power use for each person	Population density is the number of individuals per unit geographic area	number of people in a area	They both have a relation to the population and how many they are	population density is about more than one person and also in different places there could be lots of people in the area or very little people	Qatar	Qatar because it is very rich so uses a lot of electricity because there is a high demand	The more people using cars and factories the worse for the environment and will increase the damage of climate change	there will be more energy used and the will probably be fossil fuels having a negative impact on climate change	The future of energy supply in the world will be nuclear energy	solar and wind
16	It is the amount of energy usage per capita - the population distribution.	It is the number of energy used per capita or area, and tells us about how the energy is distributed amongst each country.	it is the number of 100 people per capita that live in a certain area. the higher this number the more dense that area is and the lower, the less dense.	It is the amount of people per living in a certain per every square mile.	The more dense a place, usually the more energy used, as there are more people that require energy to live. however if this country was a less developed country with a lack of resources and therefore access to energy it might not use as much	In developed countries or cities energy usage usually increases as the population density is larger, however in less developed countries sometimes the population density can be very large however with small amounts of energy usage.	Possibly Qatar as they use a lot of energy due to their country being very wealthy and developed. However they are not necessarily a big country with that large a population, therefore the density is lower.	Norway consumes quite a lot of energy, however the country has quite low population density. This might be due to the country being developed and having lots of resources.	if population densities dramatically increase it might lead to climate change and greenhouse gas emissions increasing, due to more people requiring energy and therefore more emissions.	I think that as the population densities increase around the world, the countries will become more developed and therefore using more energy, especially as the population will be larger.	I think that in the future the energy supply will decrease due to there being fewer resources available, as we are continuing to use finite resources.	i think that the future energy supply is decreasing as the population is growing more and more due to technology advancing and people needing more energy to live their lives.

17	energy per capita.											
	It is the use of energy per person in a country	The consumption of energy per area.	It is how populated the country or area is.	The amount of people and population located in the area.	The energy use per capita firmly depends on the population of the area because the bigger the population is, the more energy it requires to provide for all the people.	The bigger the population is, the more energy is required. However, it also depends on the amount of research or development occurring in the area eg. Iceland has a very small population but masses of energy consumption.	I cant think of any countries however the reason for lots of energy use is that the country may be developing and therefore requires energy to evolve and develop its infrastructure or technology.	Iceland and the Caribbean use a lot of energy as seen in the 2016 arc GIS map, this probably because most factories, industries are developed and used in that area.	I think that the bigger the population is, the more climate change will occur. Lots and lots of waste and energy will be required to provide for the up going population and it will disrupt the climate greatly.	The more the population grows the more energy it will require for all of the population.	I think that most of the countries will develop a renewable source of energy and it will power the whole country, but some countries will still depend on fossil fuels.	I think that most countries will evolve to use more natural energy sources and renewable sources. However, a lot of the other countries will rely on non-renewable sources and fossil fuels just because they are developing and require more energy