Developing the higher-order thinking skills of middle-school Geography students using Geographic Information Systems (GIS): A study of Direct Instruction and Guided Discovery pedagogies and the impact of additional multimedia scaffolding and teacher modelling

A thesis

submitted in fulfilment of the requirements for the degree of

Doctor of Philosophy

by

John Craig Kinniburgh

PGCertResMeth (Macq), GradDipEd (UNE), BA (Syd), MSc (Oxon), CGeog, FRGS, MACE

Department of Educational Studies

Faculty of Human Sciences

Macquarie University

2017

Statement of Original Authorship

The work contained in this thesis has not been previously submitted to meet the requirements for an award at this or any other higher education institution. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made.

Ethics approval was granted by the Faculty of Human Sciences Ethics Research Office on 17 February 2011 to complete the study (Ref No: 5201001530).

Signature: ______________________

Date: 24/11/17

Acknowledgements

There are so many people to thank, as without them, this thesis would never have been considered or commenced, let alone completed.

Over twenty years ago, George Dailey introduced me to the wonderful world of GIS and its potential in Geography education. His inspiration and friendship pointed me in the right direction and this provided me with opportunities to explore my passion.

My primary supervisor, Dr. Grant Kleeman, provided extraordinary oversight and support of this project from concept to completion. His measured and well considered advice, friendship and understanding of life’s challenges, was unwavering and for that I am eternally grateful. My Associate supervisor, Associate Professor Matt Bower, always challenged me to produce nothing short of my best. His counsel and advice, in all aspects of this work, was simply incredible and without his guidance, this thesis would never have been completed. Their support was a constant throughout my candidature and their friendship always valued.

I must also acknowledge the school and students where this whole thing began, way back when. Special thanks go to Drew Collins for his support and willingness to administer the interventions to the students. His support and encouragement throughout, and his willingness to accommodate my personal undertaking, is greatly appreciated. To the leadership team who allowed me to pursue my interest in GIS, as well as the students who participated in this research.

While it often seemed to be a lonely endeavour, nothing like this can occur without some impact on those close to heart. The genuine interest in my progress that was shown by family and friends, offered a constant supply of encouragement and confidence. My thanks to you all.

My research and subsequent candidature, coincided with the births of my three children, and several challenging life experiences. I acknowledge that I have missed so many hours of their childhood while labouring on this project. It is my hope that they did not notice my absence as much as I did. While the lost time can never be reclaimed, I give them my all, from this point forward.

Finally, to my beautiful wife, Jo, who has earned my greatest gratitude and admiration. Words cannot describe how grateful I am for the support she has given to me throughout this undertaking. She sacrificed so much at a personal level but always maintained belief in me to get the job done. Also, from time to time and with good humour, she kept me measured by showing polite interest in my endeavours. Thank you for your love, patience and understanding.

> Consult not your fears but your hopes and dreams. Think not about your frustrations, but about your unfulfilled potential. Concern yourself not with what you tried and failed in, but with what it is still possible for you to do.
>
> —Pope John XXIII

Abstract

This thesis examines how, and to what extent, Geographical Information Systems (GIS)-based pedagogies and practices enhance the higher-order thinking skills of middle-school geography students. In doing so, it sought to investigate the influence of pedagogical orientation, ability level and specific instructional design approaches on GIS-based learning. The findings outline how to understand, document and interpret GIS-based pedagogical approaches that are most effective in improving student thinking and learning outcomes. The key design principles identified seek to change and improve the educational practice in this area and contribute to the body of research around GIS-based instructional frameworks.

This thesis examined the key components of optimal GIS-based pedagogy for the classroom. This was achieved by investigating the effect of different pedagogies (direct instruction and guided discovery) on thinking performance at different levels. The study was conducted within the context of secondary geography education in New South Wales, Australia. The sample for the study consisted of students commencing Year 9 (9th Grade) at an independent boys' school in Sydney.

A design-based research framework was adopted as the overarching methodological approach, with mixed method techniques employed within three iterations to evaluate the effect of different interventions. A concurrent nested design was used, with the quantitative research approach being dominant and the qualitative research playing a complementary but important role. A 2 x 2 counterbalanced repeated measure design was applied to collect quantitative data, while open-ended survey questions and focus groups provided qualitative feedback from the participants.

The outcomes indicate, firstly, that pedagogy did not emerge as a key factor influencing learning outcomes within the GIS-based units completed in the interventions. Secondly, middle-ability students were unable to develop their higher-order thinking skills, compared with those students of high ability, without the explicit introduction of different forms of multimedia scaffolding and teacher modelling. The final and important result of this research was that well-targeted and constructed multimedia-based scaffolds, as well teacher modelling, can assist middle-ability students to develop their higher-order thinking skills during GIS-based learning tasks. This outcome was achieved after careful consideration of student ability and appropriately designed scaffolding during the GIS-based activities administered during the study.

Table of Contents

List of Tables

List of Figures

Chapter 1: The research context

1.1 Background to the research topic

Students today have opportunities to learn in ways that are unique and different to those of previous generations. Rapid changes in personal technologies and mobile computers, as well as the Internet, have resulted in numerous tools becoming available to students and teachers allowing them to actively engage with their learning in ways not previously possible.

> With the proliferation of the Internet in the last two decades, we are now living at a time when high-quality resources are widely available to many. Novel discipline-specific technologies and practices provide new ways for teachers to help students understand the key concepts and skills of their subjects (Bower, 2017, p.116).

For teachers and students of geography, Geographic Information Systems (or GIS) have emerged as a unique and innovative tool with the potential to enhance the quality of learning in geographical education. As a computer application, a GIS can capture, store, manage, analyse and display geographic information that is spatially referenced to the Earth's surface. When processed appropriately, the data in a GIS can be used in diverse ways to make decisions and solve problems such as "designing routes for buses, locating new businesses, responding to emergencies, and researching climate change" (Milson, Demirci & Kerski, 2013, p.3).

GIS and other geospatial technologies are now ubiquitous in society, with the technology playing a key role in a wide range of societal, organisational and governmental sectors that rely on geographical data. Many domains require accurate decisions to be made from the processing of this data for example urban planning, geology, sociology, demography, biology, security, real estate, energy and natural hazard management. The rapid advance of computing hardware capability, software development, and the availability of spatial data have allowed GIS to evolve rapidly from an isolated set of computer tools to a "powerful platform to analyse, understand, and manage the Earth in nearly every sector of society, including education" (Kerski, Demirci & Milson, 2013, p.232). At one point, the technology was also listed among the 25 most important developments that have affected the life of humanity in the 20th century (Cook, Collins, Flynn, Cohen & Budiansky 1994).

The adoption of GIS in educational settings began at university level soon after its development in the 1960s. Due to its ability to manage and analyse numerous forms of geographical data, GIS was also embraced in secondary educational settings, particularly geography classrooms, from the early 1990s. Since then, geography teachers and students have explored its use and application in a variety of different school-based educational settings (Alibrandi & Baker, 2008).

GIS was originally used to promote careers in science and engineering (Goodchild & Kemp, 1990), although the rationale for using GIS in secondary school classrooms shifted in the 2000s to support "current pedagogical aims, including the active role of learners, the collective and contextual nature of a learning process, and the orientation towards competencies and higher-level thinking skills" (Riihela & Maki, 2015, p.15). This rationale resulted in numerous educators in several countries exploring the potential of GIS to enhance the teaching not only of geography but also of other subjects, including environmental studies, social sciences, science and mathematics (Bednarz, 2004; Bednarz & van der Schee, 2006; Demirci, 2011; Hagevik, 2011; Kerski, Demirci & Milson, 2013; Lateh & Muniandy, 2011; Rød, Larsen & Nilsen, 2010).

Within secondary school settings, and in particular geography education, GIS is recognised by students and teachers for its potential to empower students to be active learners through the process of geographic inquiry. Audet and Paris (1997) noted that the features of a GIS that appeal to educators include its ability to use geographic data to swiftly and dynamically represent the world and its issues from a variety of perspectives. Students can use the functions and tools of a GIS to manipulate and query spatial data to solve a wide range of geographical problems (Wigglesworth, 2003) and this means it is suitable for constructivist and inquiry-oriented methods of analysis (Bednarz, 2004; Kerski, 1999). The diverse functionality of a GIS allows teachers to conduct problem-solving activities in the classroom that enable students to explore geographical issues and enhance their geographic knowledge and understanding (Bednarz, 2004; Johansson, 2006; Lloyd, 2001; Patterson, Reeve & Page, 2003).

It was noted more than 15 years ago that GIS encouraged students to collaborate, take responsibility, and think critically and creatively (e.g. Keiper, 1999). When learning occurs in this way, students can participate in educational activities that reportedly enable them to engage in higher levels of thinking and learning and make decisions through the study of real-world problems and social and scientific concepts and processes (Kerski, 2008; Milson & Kerski, 2012). It is now widely acknowledged within the literature that GIS is a tool that develops spatial thinking skills, and helps students visualise spatial and non-spatial data and ask geographically focused questions

(Bednarz, 2004; Bednarz & van der Schee, 2006; Huynh, 2009; Lee & Bednarz, 2009; Marsh, Golledge & Battersby, 2007).

Given the perceived educational benefits of GIS, it is not surprising that the use and application of GIS in secondary education has occurred in a wide range of educational settings around the world, with geography educators keen to explore its potential (Liu & Zhu, 2008). Institutional recognition has also occurred, with the National Research Council (2006), for example, identifying GIS as a powerful tool that can reshape learning across the curriculum, particularly when used by well-trained and imaginative teachers and within effective school infrastructures.

Despite its apparent potential, several studies since 2000 have reported low rates of GIS implementation within school settings (Alibrandi & Baker, 2008; Kerski, 2000; Chalmers, 2006; Kerski, 2003; Kidman & Palmer, 2006; Kinniburgh, 2008; Meaney, 2006). Several authors have also drawn attention to the reasons for the limited uptake of GIS (e.g. Kankaanrinta, 2004; Lam, Lai & Wong, 2009) and these are outlined in more detail in Section 1.6. While the impediments to wider implementation are noted, it is generally acknowledged that early adoption of GIS in the first decade of the 21st century relied on enthusiastic and pioneering teachers who were individually motivated to implement the technology into their classes.

Despite the positive intentions of these enthusiastic educators, there was little evidence to support the benefits and learning outcomes of GIS, as was noted by several authors over ten years ago (see Baker, 2002; Baker & Bednarz, 2003). A decade later, and with scant improvement in this regard, attention is now being drawn to the need for more focused research to be undertaken into the affordances of GIS within a range of settings (Baker, Kerski, Huynh, Viehrig & Bednarz, 2012; Bednarz, Heffron & Huynh, 2013). Baker et al. (2015, p.118) note that the research undertaken to date to identify the benefits of GIS has been limited and “rarely replicated or brought to scale”).

This study responds to this call by exploring how GIS can be effectively integrated within the secondary geography classroom by focusing specifically on pedagogical frameworks that engage and develop student thinking skills.

1.2 The importance of geography education

In their position paper, *Geographical Education in Australian Schools* (submission to the Minister for Education, Science and Training, November 2006, p.1) the Institute of Australian Geographers and the Australian Geography Teachers Association (2006) state that geographical education is ‘essential to the development of all young people and to the economic, environmental and cultural future of Australia'. Geography:

- is concerned with the current and future challenges such as climate change, water and land management, and ageing populations;
- has strong vocational relevance;
- engages students with its real-world content and its active learning styles;
- creates spatially literate students;
- encourages students to be informed, responsible and active citizens, and prepares students for the world after school; and
- nurtures in students an appreciation of biophysical environments and the resources they provide.

As a discipline, the study of geography provides a richly diverse experience of the changing and interconnected world in which we live, focusing on the natural world and resources, as well as cultures, economies and societies. The discipline also involves the study of people and the places in which they live, of global development and of citizenship; this scope is encapsulated by Michael Palin, immediate Past President of the Royal Geographical Society with IBG (2015), who states:

> So many of the world's current issues – at a global scale and locally – boil down to geography, and need the geographers of the future to help us understand them. Global warming as it affects countries and regions, food and energy security, the degradation of land and soils from over-use and misuse, the spread of disease, the causes and consequences of migration, and the impacts of economic change on places and communities.

According to the Australian Curriculum, Assessment and Reporting Authority (ACARA):

> Geography is a structured way of exploring, analysing and understanding the characteristics of the places that make up our world, using the concepts of place, space, environment, interconnection, sustainability, scale and change. It addresses scales from the personal to the global and time periods from a few years to thousands of years. Geography integrates knowledge from the natural sciences, social sciences and humanities to build a holistic understanding of the world. Students learn to question why the world is the way it is, reflect on their relationships with and responsibilities for that world, and propose actions designed to shape a socially and sustainable future. (Australian Curriculum, Assessment and Reporting Authority (ACARA), 2017)

Early statements about the value of geography (including Casinader & Casinader, 1994) have highlighted the importance of students thinking critically in geography, while Hicks (2007) noted that when students develop a futures dimension or perspective on their lives and on the world, they will:

- develop a more future-oriented perspective on their lives and events in the wider world;
- exercise critical thinking skills and the creative imagination more effectively;
- identify and envision alternative futures that are more just and sustainable; and
- engage in active and responsible citizenship in the local, national and global community, on behalf of both present and future generations.

1.3 Geographic inquiry

Geography education has progressed from being a subject that once required the memorisation of geographical facts to one that more commonly incorporates the geographic inquiry process. This shift results in students being able to develop more comprehensive responses to questions relating to their future via "an active process through which learner's construct knowledge about the world" (Roberts, 2003, p.51). It is largely a geographic process as it is "about the places, spaces, people and their complex interrelationships" (Kriewaldt, 2006, p.24).

Some authors emphasise the importance of linking knowledge with skills in geography education (Bednarz, 2000; Morgan, 2006), while others suggest that the problems, tasks, and settings of geography education should be meaningful, realistic and relevant for students. "Students should learn how to do geography: they should develop the knowledge, skills, and motivation to engage in geographic inquiry" (Favier & van der Schee, 2012, p.666).

As a result, contemporary geography curriculum frameworks tend to encourage an inquiry-based approach to help develop students' decision-making skills and problem-solving abilities so that they can analyse societal issues and consider the future in a more cohesive and creative manner. Inquiry-based instruction is aligned with constructivist learning theories, with the central tenet being that students learn best in collaborative learning environments in which they work on problems in authentic contexts (Doğru & Kalender, 2007; Guthrie et al., 2004; Hmelo-Silver, Duncan & Chinn, 2007). The key point identified here is that the learning processes are most effective when "students actively make sense of the subject matter themselves" (Favier & van der Schee, 2012, p.667).

The process of geographical inquiry is also promoted by the Australian Curriculum, Assessment and Reporting Authority (ACARA), which states that:

> Geographical inquiry is a process by which students learn and deepen their understanding. It involves individual or group investigations that start with geographical questions and proceed

> through the collection, interpretation, analysis and evaluation of information to the development of conclusions and proposals for actions. Inquiries may vary in scale and geographic context. (Australian Curriculum, Assessment and Reporting Authority, 2017)

1.4 Geographic Information Systems (GIS)

There are several definitions of Geographic (or Geographical) Information Systems, which have evolved and developed in a variety of fields and disciplines. Early definitions referred to GIS as a 'tool'. For example, "A Geographical Information System is a powerful set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes" (Burrough, 1986, p.6). Huxhold (1991, p.3) defined a GIS as a "collection of information technology, data, and procedures for collecting, storing, retrieving, manipulating, analysing, and presenting maps for descriptive information about features that can be represented on maps". Following on from this, Green (2001) notes that definitions like this are quite technical, as they refer to hardware, software and spatial data.

GIS is, therefore, often misunderstood by teachers who are not necessarily familiar with the variety of terms used in relation to the technology, and this misunderstanding has led to several definitions more suitable for education being developed. Rød, Larsen, and Nilsen (2010, p.22) in broad terms define GIS as a "set of tools that transforms geographical data into geographical information and thereby increases our knowledge and/or helps us to solve geography-related problems". These definitions acknowledge GIS as a tool, in the same way as Burrough's definition does, but use cognitive rather than technical terms. In its simplest sense, a GIS is a database with mapping capabilities, and one that offers a way to manage, analyse and visualise geographical information that is spatially referenced to the Earth's surface.

A fully operational Geographical Information System typically contains several key components that are important for its function to be effective. These are:

> **Hardware:** this is the centralised computer or server, upon which the GIS software operates. A GIS requires robust hardware and specifications, particularly when using, for example, image files, which are large in size.
>
> **Software:** The GIS software provides the tools and functions that are needed to store, check, analyse and display the information stored and created.

Data: Geographic data can be collected by the user, created using a spreadsheet or purchased from a data provider. A GIS can also integrate data from other sources on the web, as well as store the data locally or on a server. Data is in either vector or raster format.

Analysis: Refers to the rules and procedures that the individual user follows to operate the GIS in such a way as to produce intended outcomes.

People: The individual/s operating the GIS are the most important component and their skills will range in ability, from basic to advanced users.

The GIS software analyses the different layers of data to explore patterns and relationships, and in doing so create and visualise new layers of data or geographic information. In summary, a GIS works by 'layering' different thematic data layers (Figure 1).

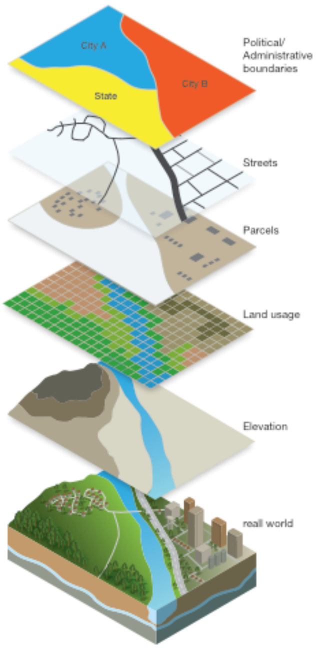


Figure 1. Image showing the concept of layering in a GIS
Source: (Australian Geography Teachers Association (AGTA))

1.5 The benefits of using GIS in the classroom

For well over twenty years, school geography teachers (particularly those in secondary or high school settings) have sought to integrate GIS into curricula and classroom practice (Hicks, 2007). GIS has, for example, been widely deployed by teachers and educators to teach subjects in social studies and humanities such as geography, as well as science (Akinyemi, 2015). It has also been shown to benefit the teaching of these subjects at both primary and secondary levels (Bednarz & Ludwig, 1997; Kim, 2010; Nielsen, Oberle & Sugumaran, 2011; Sinton, 2009).

More recently, this interest has continued in positive attempts being made to use GIS to enhance teaching and learning (see Kerski et al., 2013; Srivastava & Tait, 2012). The National Research Council, among others, has specifically identified GIS as a powerful tool that can reshape learning across the curriculum, particularly when used by "well-trained and imaginative teachers" along with effective school infrastructures (Alibrandi & Baker, 2008, p.3).

The level of interest in using GIS has largely been driven by educators who identified GIS as an educational tool rather than a technology. Many authors have argued that, when placed at the centre of various inquiry-based learning activities, GIS facilitates the adoption of student-centred (or constructivist) approaches to teaching and learning (Audet & Paris, 1997; Bednarz & Ludwig, 1997; Johansson, 2003; Kerski, 2008; Kinniburgh, 2010; Landenberger, Warner, Ensign & Nellis, 2006; Lemberg & Stoltman, 2001; Meyer, Butterick, Olkin & Zack, 1999; Wanner & Kerski, 1999; White & Simms, 1993). Favier and van der Schee (2012, p.666) suggest that "GIS-supported inquiry-based geography education has the potential to contribute to deep geographic learning in a manner that is different from traditional geography education".

When a student adopts an inquiry-based approach using a GIS, the result is instantaneous feedback as they manipulate different layers and datasets (National Research Council, 2006, p.177). By utilising the tools of the GIS to perform functions such as spatial querying, statistical analysis and visualisation, the user can 'search' for answers by 'interrogating' or 'querying' attribute tables held within spatial datasets, which produces a learning outcome (Figure 2).

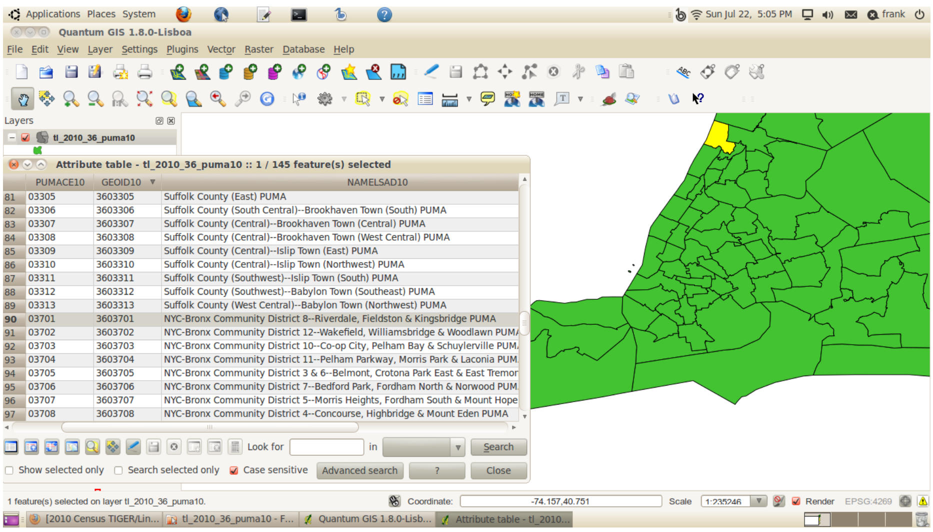


Figure 2. Screenshot showing attribute table for a data layer dispplayed in a GIS

Source: Gothos (2012)

The aspect of a GIS that makes it beneficial for use by geography teachers and students is that it provides a powerful alternative to paper-based maps as the primary spatial representation and analysis tool. It is, therefore, possible to address spatially explicit real-world problems and enhance spatial thinking skills by visualising spatial and non-spatial data (Marsh, Golledge & Battersby, 2007; National Research Council, 2006). These skills can also be further enhanced with the use of other geospatial technologies (e.g. Huynh, 2009; Lee & Bednarz, 2009). There is a strong parallel emerging between the educational use of GIS and the increased use of spatial technology in society. Geographic information is becoming "progressively ubiquitous in everyday life as location-aware capabilities have been integrated into consumer-oriented devices and services" (Riihela & Maki, 2015, p.15). This ubiquity, coupled with web-based GIS applications, means that GIS will become more readily accessible to novice users and advantaged by the ability to connect to cloud-based data collection services, such as crowdsourcing networks (Baker, 2015).

Since 2000, there has been a shift in focus towards student learning outcomes and the actual benefits of GIS education to students. Research has informed discussion about whether GIS is an effective tool to promote learning and develop students' critical thinking and analytical skills (Alibrandi, 2003; Baker & White, 2003; Bednarz & van der Schee, 2006; Bloom & Palmer-Moloney, 2004; Hagevik, 2003; Johansson, 2003; Kerski, 2000, 2001; National Research Council, 2006; Pang, 2006). Sinton and Lund (2007), however, provided an important qualification during this period by observing that the GIS itself does not produce learning, but rather allows teachers and students to engage in more sophisticated inquiry than would otherwise be possible and can, as a result, transform secondary geography education. This is a view supported by Kerski et al. (2013, p.233), who note that GIS use can encourage "collaboration, student responsibility, critical thinking and creativity among students".

One of the central arguments for using GIS is that the use of GIS in the classroom supports contemporary educational pedagogies, particularly those that are inquiry-based and encourage the active role of learners. It is also widely noted in the literature that, with well-trained teachers and well-equipped schools, GIS can be used to foster critical thinking and problem-solving skills among students, especially when linked with other types of media and fieldwork (Alibrandi, 2003; Bloom & Palmer-Moloney, 2004; Demirci, 2008; Hagevik, 2003; Johansson, 2003; 2001; National Research Council, 2006; Pang, 2006). Other authors have also noted a strong alignment of GIS-based instruction with the learning process, competences and the development of high-order thinking (National Research Council, 2006; Drennon, 2005; Gryl & Jekel, 2012; Kulo & Bodzin, 2013; Ratinen & Keinonen, 2011).

More recently, there has been a strong focus on using GIS to help students engage in public discourse and policy analysis (Hogrebe & Tate, 2012) as well as investigations that engage with real-world problems, social concepts and processes (Kerski, 2008; Milson & Kerski, 2012). GIS also supports multi-disciplinary approaches to investigating community issues (Jenner, 2006) via open-ended investigations and the visualisation of real-world problems (Henry & Semple, 2012; Lay, Chi, Hsieh & Chen, 2013). According to Baker et al. (2012, p.255), GIS "helps students think critically, use authentic data, and connects them to their own community". It has also been noted that community-based or participatory GIS is beneficial in empowering residents in small communities to "explore and map their local knowledge of natural resources, community risk, and political argumentation" (Sinha et al., 2017, p.165). Furthermore, it has been suggested that the skills developed while engaging in GIS-based investigations situated within a real-world context can be applied to a range of vocational contexts. The exercise is not just an academic one, as the geospatial technology sector has also been identified as "one of the key industry growth sectors in which Australia has a global competitive advantage" (Spatial Industries Business Association, 2016, p.2).

Drawing on the literature outlined above, Bednarz (2004, pp.192–93) summarises the affordances of GIS-based education through three justifications:

1. the educative justification, where the use of GIS enhances students' spatial thinking skills;
2. the workplace justification, where GIS is an essential tool for future knowledge works; and
3. the place-based justification: where GIS is an ideal tool to study the environment of a local community.

1.6 GIS trends and challenges

Despite strong arguments in support of the benefits of GIS-based education, much of the early promise of GIS in the classroom has yet to be realised and questions have been raised about its value and potential (Bednarz & van der Schee, 2006; Liu & Zhu, 2008; National Research Council, 2006; Wheeler, Gordon-Brown, Peterson & Ward, 2010). The uptake and use of GIS in education is "not at a rate commensurate with expectations" (Bednarz & van der Schee, 2006, p.192).

Since 2000, several studies have highlighted the slow adoption and use of GIS by teachers in various educational settings (see Hohnle, Schubert & Uphues, 2013; Kerski, 2001; Kinniburgh, 2008). Despite continued growth in individual settings and "the fact that GIS in secondary education is in its third decade, it is still largely ignored by the majority of secondary educators" (Kerski et al., 2013, p.242).

There has been considerable debate about the reasons more teachers have not embraced GIS, with several contextual challenges identified in the literature. These include prohibitive costs to introduce GIS in schools (Bednarz & van der Schee, 2006; Kinniburgh, 2008; Walden University, 2010), limitations of school technology infrastructure (Milson & Roberts, 2008), lack of effective teacher training programmes (Doering & Veletsianos, 2007a), teachers' lack of familiarity, knowledge and comfort with using GIS technology (Hohnle et al., 2013) and lack of curriculum-specific references (Eksteen, Pretorius & Breetzke, 2012). Other researchers highlight country-specific challenges that limit the effective use of GIS in education systems within those contexts (Ayorekire & Twinomuhangi, 2012; Kerski et al., 2013; Kim, Bednarz & Lee, 2011). Demirci (2015) identified the conditions affecting the use of geospatial technologies such as GIS in education (as shown in Figure 3), highlighting the technological, pedagogical and political impediments to implementation.

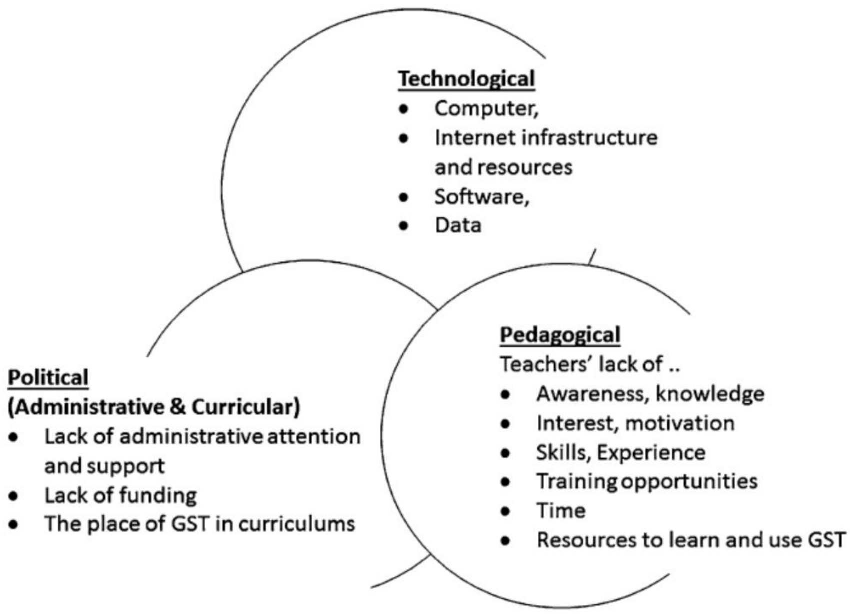


Figure 3. Conditions affecting the use of geospatial technologies (including GIS) in education
Source: Demirci (2015)

1.7 The need for GIS-related research

Following on from the identification of impediments affecting the use of GIS in education, it is not possible to unequivocally state that the use of GIS in secondary education has a clear and positive impact on geographical education (Bednarz & van der Schee, 2006). While the potential benefits of GIS-based technologies have been widely promoted, a detailed body of research-based literature that highlights significant learning in geography is generally lacking. Consequently, the debate continues about the capabilities of GIS and its actual benefit to education (Kankaanrinta, 2004; Kerski, 2003; Kerski et al., 2013; Lam et al., 2009; J. Lee & Bednarz, 2009; Møller Madsen & Rump, 2012; Sinton, 2009). What does exist appears limited, fragmented and rarely replicated, with the few extant studies offering limited insight only into the benefits of GIS (Baker et al., 2015; Baker et al., 2012).

Empirical studies that showed the effects of GIS on geographic learning, motivation, spatial ability and problem solving, only began to appear in the late 1990s (Huynh, 2009). Many of these studies are qualitative and theory-based, although more quantitative studies have emerged in recent years (Demirci, 2015). These include a study by Y. Liu et al. (2010) conducted in a Singapore secondary school in which problem-based learning using GIS was evaluated in experimental and control groups. It was observed that students in the control group showed memorisation skills while students in the experimental group demonstrated higher-level cognitive learning skills, and analytical and evaluation skills. There are, however, a number of limitations with this study and these will be discussed in the Literature Review.

Another study, by Perkins, Hazelton, Erickson, and Allan (2010), found that a three-day GIS/GPS curriculum experience significantly increased students' spatial awareness. Another example includes a study by Goldstein and Alibrandi (2013), who conducted a quantitative study (with and without GIS instructions) on standardised test scores of two groups of middle-school students from different cultural backgrounds. It was found that GIS instructions significantly affected students' achievement on reading scores and on final course grades in both science and social studies.

The studies undertaken up to the early 2000s were based on assumptions that GIS and other geospatial technologies (GSTs) supported constructivist learning environments; however, there was little attempt to examine the pedagogical evidence for the effectiveness of the tool (Biilmann, 2001; Keiper, 1999; Lemberg & Stoltman, 2001).

Shortly after this period, several key studies explored the value of GIS as a tool to enhance learning in geography education and its potential for teaching and learning when used with appropriate methods of instruction (including Baker, 2002; Baker & Bednarz, 2003; Baker & White, 2003; Bednarz, 2004; Demirci, 2015; Keiper, 1996; Kerski, 2003, 2008; Patterson et al., 2003; West, 2003). Other studies have highlighted concerns that teaching with geospatial technologies like GIS has not targeted higher-order thinking skills, particularly in secondary education, and "therefore the effectiveness of Geospatial technologies has not been proven" (Demirci, 2015, p.147).

Key concerns have emerged due to the lack of research on the outcomes of experimental studies evaluating the effectiveness of teaching with geospatial technologies (Favier & van der Schee, 2014; Kerski et al., 2013; Kim et al., 2013). West (2008, p.96) noted that there is little evidence whether "GIS enables students to attain the goals of geography education". There are few research-based studies that highlight the ongoing benefits of GIS; existing studies in this area are limited, with little guidance given on how best to use the technology (Baker & Bednarz, 2003; Baker et al., 2012). To support teachers, researchers should "provide more insights on how to make the best use of GIS in geography teaching" (Lam et al., 2009, p.72).

With an obvious gap between the perceived educational value of GIS and the challenges faced by teachers when using the technology in the classroom, "there is a recognised need for better approaches to the adoption of GIS at the K-12 level of education" (Henry & Semple, 2012). This research, therefore, seeks to identify how student learning can best be accomplished using GIS technology by identifying effective instructional approaches. It also takes place amidst a wider call for research to determine whether GIS (and other GSTs) are effective for teaching and learning. As noted by Baker et al. (2015, p.1), there is a need to conduct research to highlight "knowledge gaps, encourage engagement from broad-based scholarly teams, and inform new audiences about this rich research area".

1.8 The need for GIS-based pedagogies

Since Sui (1995) first distinguished between teaching *about* GIS and teaching *with* GIS, there has been little guidance regarding the use of GIS-based pedagogies in education. As GIS education gained traction among geography teachers after 2000, it was identified by Kerski (2000) that there was a lack of understanding about the relevance of GIS in the geography curriculum, and of valid pedagogical approaches that could facilitate its use. Bednarz (2004) concluded that "scant attention has been paid to issues related to pedagogy and GIS" with little known about optimal design features for GIS-supported geographical inquiry projects. The need for models of pedagogy is also supported by Doering, Veletsianos, and Scharber (2008).

Goldstein and Alibrandi (2013) more recently observed that, while there are pedagogical benefits of GIS in the K–12 school curriculum, a documented relationship between GIS instruction and student academic achievement using standardised test measures is lacking. As education changes to reflect new educational needs, strategies for integrating technologies (like GIS) into teaching and learning, and which support contemporary pedagogies, must also be addressed. Therefore, the development of appropriate instructional frameworks that allow teachers to implement GIS in their classroom, and that result in observable learning outcomes, is a worthwhile priority and provides the focus for this study.

1.9 The Australian school context

Australia has a three-tier schooling model that includes primary, secondary and tertiary education. Each Australian State and Territory oversees its own education system, with secondary schooling typically from Years 7 or 8 through to Year 12. Education in Australia is compulsory between the ages of 5 and 17 and the minimum leaving age is generally at the end of Year 10. There are two main education sectors within each State and Territory, Government and Non-Government schools. Non-Government schools are classified as either Catholic or Independent. Most Independent schools have a religious affiliation, but some are non-denominational, and all Government schools are non-denominational or secular institutions (Australian Schools Directory, 2015).

All Australian schools, irrespective of whether they are part of the Government, Catholic or Independent systems, are expected to follow the Australian Curriculum as determined by the respective governing educational authority in each State or Territory. The current Australian Curriculum was officially endorsed in 2015 and sets the expectations for what all students in Australia should be taught, irrespective of where they live in Australia or their background. It provides curriculum documents in eight key learning areas, including English, Mathematics, Science, Humanities and Social Sciences, The Arts, Technologies and Health and Physical Education. Students in all Australian schools have access to these courses or the State/Territory-based iterations of the Australian Curriculum. As each state or territory provides its own secondary education curriculum, there is some inconsistency in what is taught. For example, both New South Wales and Victoria have structured curriculum documents (developed from the Australian Curriculum documents) that compel educators to teach content-specific detail. Others, including Queensland, have broader curriculum frameworks from which lesson content is administered. Following their time at school, students can also apply to attend university, further education colleges and technical institutes. Some schools also provide vocational training for students, which helps some students access job prospects earlier.

The Australian Curriculum in geography includes a Years 7–10 curriculum as well as a senior secondary curriculum. The Years 7–10 curriculum addresses geographical knowledge and understanding by providing opportunities for students to investigate, analyse and explain the characteristics of certain places within the world by studying seven key concepts – place, space, environment, interconnection, sustainability, scale and change. Geographical inquiry and skills are also developed through fieldwork and within the classroom.

In senior secondary geography, students develop knowledge and understanding about specific themes that can be applied at different scales, from local to global. Within this framework, there are four units studied – natural and ecological hazards, sustainable places, land cover transformations and global transformations. Students also undertake Geographical inquiry and develop geographical skills in their studies.

Generally, there exists a strong expectation in Australian State and Territory geography curriculum documents that young people will develop Geographical knowledge and understanding through the concepts of place and space, develop key geographical skills and also undertake investigations through inquiry. There are, however, variations in what is taught in geography between each State and Territory, as each region has control over the content and topics taught in primary and secondary schools. Currently, New South Wales is the only state or territory that requires all students to complete geography as a core subject before the end of their compulsory years of school (end of Year 10). Two hundred hours of geography are mandated over Years 7–10, while in other States and Territories students cover a combination of social science areas, together with history, within the compulsory humanities and social science subject areas. In most States and Territories at the senior secondary level, geography is often available to students as an elective subject.

1.10 Research questions

The aim of this research is to investigate and evaluate the components of GIS-based pedagogies that improve student learning outcomes and thinking skills. The research seeks to evaluate the effect of different GIS-based pedagogies, as well as student ability levels, on the development of geography students' higher-order thinking skills within a middle-school context. It is anticipated that the design principles identified in this research will enhance the confidence of teachers in delivering effective GIS-based investigations in their own respective schools.

The central research question is:

- How, and to what extent, do GIS-based pedagogies and practices enhance the higher-order thinking skills of middle-school geography students?

The research will also examine the following sub-research questions:

1. To what extent does the pedagogical orientation of the lesson influence learning in GIS contexts?

2. Does ability level influence the development of student thinking skills using GIS?

3. How can students be best supported to develop higher-order thinking skills using GIS?

1.11 Organisation of the thesis

This thesis investigates the central research question and sub-questions stated in Section 1.10. Chapter 1 has provided the contextual background to the study, including a rationale for the investigation; has outlined relevant details relating to the broad topic of geography education as well as the notion of geographical inquiry; and provided a general overview of Geographic Information Systems (GIS), the benefits and challenges of GIS and the need for GIS-related pedagogies to enhance students' geographical understanding and thinking skills. The chapter closed with a brief outline of the Australian school context within which this study takes place.

Chapter 2 presents a detailed literature review of information and related research relevant to this study. It specifically outlines relevant theory relating to the nature of learning and instructional approaches that facilitate learning outcomes. The chapter then reviews relevant information pertaining to student thinking skills and, specifically, how student thinking skills can be developed in Geography education, as well as the link between GIS and appropriate instructional frameworks that enhance student thinking outcomes. The chapter also reviews the notion of scaffolding to support learning and reviews the implications of different forms of scaffolding that are relevant to this study. The chapter closes by drawing together the key themes of geographical inquiry, student thinking skills, scaffolding and student ability levels.

Chapter 3 outlines the methodology that was adopted to complete the study. It begins with a review of the theoretical background of design-based research (DBR), which underpins the methodology chosen, before reviewing the nature of the mixed methods research approach that was used to complete the study and provides contextual information relating to the participants. The procedures followed are then explained, and this is followed by a detailed summary of the variables considered in the study. The research instruments are then discussed, as are the quantitative and qualitative analysis techniques used. The chapter closes with a discussion of the issues of validity, ethical consideration and limitations of the methodology.

Chapter 4 presents the quantitative and qualitative results of the study, presented sequentially. Within each intervention, the quantitative results are presented first, followed by the qualitative results from the survey and focus group interviews.

Chapter 5 presents the Discussion and Conclusion, opening with a summary of the research context and rationale for the study. It then provides, in detail, a clear outline of the key findings and specifically the implications of the findings, along with the study's recommendations. The study's limitations are then discussed and opportunities for future research identified. The chapter closes with a brief concluding statement regarding the future of GIS education.

A comprehensive reference list and appendices are included at the end of the thesis.

Chapter 2: Review of the literature

2.1 The nature of learning

This research seeks to ascertain how GIS can improve learning outcomes and improve higher-order thinking skills. If this is to be achieved, the development of valid instructional frameworks, informed by recognised learning theory, is required. There are numerous perspectives on teaching practice and pedagogical approaches, so a review of the literature on learning theories and how people learn is an important starting point. Through careful and considered evaluation of the literature around learning theory, it is possible to ensure that the research methodology is informed by the language and discourse of valid educational paradigms. This allows new perspectives on how GIS can assist students to learn and become more knowledgeable to be considered.

The complex nature of learning has figured prominently in educational discourse and debate over the past 10–15 years (Illeris, 2009). Learning is complex, as "it involves a variety of elements, each of which interact to produce effective learning … there is no one, universal explanation of how we learn nor are there guidelines about how we should teach" (National School Improvement Network, 2002, p.1). While the results of learning are often observed in human performance, the process of learning is much less obvious (Driscoll, 2005). Consequently, different theories have been developed to explain learning, each of which represents different views or perspectives.

2.1.1 Learning theories and instructional design

It is not enough for teachers to be familiar with subject matter; it is important that they also have a strong understanding of the underlying learning theory on which their instructional approach is based (Surgenor, 2010). Equipped with this knowledge and understanding, teachers can adapt their instruction to the unique characteristics of a classroom setting; in this way, "theory informs practice" (Yilmaz, 2011, p.204).

Underlying learning theories make it possible '[for teachers] to link observed changes in performance with what is thought to bring about those changes" (Driscoll, 2005, p.9). It follows, then, that a clear understanding of learning theories and the rationale behind them can contribute to the delivery of effective instruction (Newby, Stepich, Lehman & Russell, 2005).

While there is no single unifying theory of learning or instruction (National School Improvement Network, 2002), learning theories play an important role in the development of instructional designs, with the obvious aim being to provide a guide to strong teaching practice leading to an improvement in the knowledge of learners (Sotto, 2007; Surgenor, 2010).

Some writers (including Christensen & Osguthorpe, 2004; Reigeluth, 1999; Wilson, 2005) have provided guidance about principles of good instructional design generally, however, this is often 'generic' in nature, rather than being linked to any particular pedagogical approach or strategy. Merrill (2010) also observed that an understanding of learning theories can help teachers appreciate the different aspects and types of learning that can take place in a classroom. Learning theories are, therefore, an important consideration for teachers when considering the nature of the lessons they plan to deliver in a classroom.

Instructional design informs the strategies (or techniques) that teachers use to help students become independent, strategic learners. Designing effective instruction, however, goes beyond simply following the steps within an instructional design model (Shuell, 2013). As noted by McLeod (2003, p.35), it must "take into consideration the theoretical bases in which it is grounded". Other authors support this view and explain that a "theoretical tool, in and of itself, is not an instructional design theory but defines instructional components that can be used to define instructional prescriptions more precisely" (Merrill, 2001, p.294).

Learning theories do not provide solutions but rather direct attention "to those variables that are crucial in finding solutions" (Merriam & Caffarella, 1999, p.250). It can, therefore, be concluded that an understanding of theoretical frameworks is important for educators to effectively prepare and present instruction. Without this "body of theory in their 'day-by-day' practice, teachers are behaving blindly" (Bigge & Shermis, 2004, p.5). In order for a teacher to develop quality lesson plans, aimed at achieving specified learning outcomes, teachers "must possess a variety of skills and have a solid understanding of different concepts, ideas, and theories" (Brown & Green, 2006, p.46).

Learning theories can be classified along a continuum defined by the extent to which the teacher or the learner is more active or participatory in the learning process. At one end of the continuum, the teacher is dominant (behaviourism), while at the other end the learner individually constructs knowledge through interaction with the environment and others (constructivism). In the middle of the continuum is the notion that the learner requires active participation to learn and that their actions are the consequence of thinking (cognitivism). Whereas behaviourist theoretical frameworks underpin teacher-centred instruction, constructivist perspectives come into play in shaping learner-centred instruction (Yilmaz, 2011).

The following section provides a brief overview of the principal learning theories and the implications of each for the instructional design process.

2.1.2 Behaviourism

By the middle of the 20^{th} century, the dominant learning theory used in education was behaviourism (Merrill, 2001). Prominent behaviourists, with the date of their notable contributions, include Ivan Pavlov (1897/1902), Edward Thorndike (1905), John Watson (1913), Edwin Guthrie (1935, 1942), Burrhus Frederic Skinner (1936) and Clark Hull (1943, 1951, 1952).

According to behaviourists, learning occurs because of "observable changes in human behaviour that are acquired through conditioning and interactions with the environment" (Pham, 2011, p.46). If there are no observed changes in behaviour, then learning has not occurred. Behaviourists also assert that the learning environment plays a key role in shaping outcomes, with external stimulus, responses and complex learning requiring a series of small, progressive steps (Finger, Russell, Jamieson-Proctor & Russell, 2006). Their focus is on objectively observable and measurable teacher and student behaviours through a stimulus–response framework (Christensen & Osguthorpe, 2004).

Essentially, this theory of learning argues that rewards reinforce positive behaviour in learners. It is argued that, after being rewarded, the learner will repeat the actions and thereby establish a suitable means of learning (Sotto, 2007). According to behavioural theorists, educators can influence learning by determining what to teach, with objectives based on desired behaviour, which has led to the development of structured and sequential curricula, workbooks and programmed instructional approaches including drill and practice computer software (Finger et al., 2006).

Behaviourism has also had an impact upon instructional design, as it builds upon the observation that learning is based on mastering of a set of behaviours that are predictable and reliable (McLeod, 2003). The strength of instructional design grounded in behaviourism lies in its ability to find quick responses to well-defined problems (Kuchinke, 1999). A key weakness, however, is that the instructional design is dependent on the environment (for example the classroom) maintaining the appropriate stimuli to continue the intended behaviour. If a certain incentive (or reward) is not provided, then the performance may be affected.

2.1.3 Cognitivism

In the 1960s, cognitivism, the historical and conceptual bridge between behaviourism and constructivism, replaced behaviourism as the dominant learning theory. As theory, it considers learning as a change in cognitive thinking and focuses on internal mental processes that alter the way people conceptualise, realise and understand their environment (Brown & Green, 2006). In a more general sense, it refers to the study of the mind and how it obtains, processes and stores information (Yilmaz, 2011). This focus on the mind signalled a shift towards methods of instruction that relied on learning models from the cognitive sciences, with educators focusing more attention on more complex cognitive processes such as "thinking, problem solving, language, concept formation and information processing" (Ertmer & Newby, 2013, p.50).

In cognitivism, the learning foundation is based on human memory. If there is no memory, then there can be no learning. It follows that, without learning, memory becomes an 'empty vessel' (Ashman & Conway, 1997). A central assumption of cognitivism is that an existing knowledge structure (schema) must be present to compare and process new information for learning (McLeod, 2003) and this is activated when a "learner is made aware of his background knowledge and exposed to strategies to 'bridge' from pre-requisite skills to learning objectives" (Blanton, 1998, p.172).

The goal of cognitive learning is, therefore, "to develop student academic and thinking skills from a novice level to a more expert level … [and] to provide adequate experiences in which students structure the learning and teaching themselves" (Orlich, Harder, Callahan, Trevisan & Brown, 2004, p.38). Cognitivists believe that learners develop knowledge and understanding by receiving, storing and retrieving information; therefore, instructional designs modelled on this theory contain tasks that allow the learners to effectively and efficiently process the information stored (McLeod, 2003). As a result, the learner is the focus and not the environment, as is the case with behaviourism.

Learner characteristics are also important and should be considered; learning is meaningful only when it can be related to concepts that already exist in the learner's cognitive structure, meaning rote learning is easily forgotten (Merriam & Caffarella, 1999). This is, however, a major weakness of this theory, as a learner is at a disadvantage when relevant schemas or prerequisite knowledge do not exist. To address this weakness, the designer must ensure that the instruction is "appropriate for all skill levels and experiences" (McLeod, 2003, p.40).

2.1.4 Constructivism

Constructivism is a learning theory that originates with the work of Jean Piaget (1972, 1973) and incorporates other learning theories, including discovery learning (Bruner, 1961) and situated learning (Brown, Collins & Duguid, 1989). Constructivism is based on the belief that "an individual constructs his or her understanding of the world in which he or she lives by reflecting on personal experiences" (Brown & Green, 2006, p.37).

Constructivism focuses on the learners' ability to construct their own knowledge (Stavredes, 2011) through interactions with the outside world. Learners are not supposed to wait for knowledge to be 'filled'; instead, they play an active role to seek meaning and nurture self-awareness, which results in the learner often interpreting or generating new rules to comprehend ideas (Pham, 2011).

A central tenet of constructivism is that learning occurs when individuals are actively engaged in the learning process and integrate new knowledge with existing knowledge (Bigge & Shermis, 2004). The result is that the learner constructs their own knowledge from their own experiences (Finger et al., 2006) while the instructor serves as a facilitator to support learners to construct, rather than receive, knowledge.

It is often appropriate for teachers who adopt this learning theory as the basis for their instructional design to begin with the information that students know. They then lead them to new knowledge by using thought-provoking questions and scaffolding techniques (Olivia, 2009). 'Scaffolding' refers to a series of support structures embedded in the instructional framework designed to help the student build up their understanding of new concepts based on their prior knowledge (Gagne, Wager, Golas & Keller, 2005). Scaffolding plays an important role in the research undertaken.

In terms of implications for instructional design, learners' prior knowledge must be considered, along with understandings and interests. "Teachers must understand what learners bring to the learning situation and being there in helping students build new knowledge" (Boethel & Dimock, 2000, p.17); in this respect, constructivism resembles cognitivism. This approach to learning is also more open-ended in expectation, and the results are often not easily measured, nor may they be consistent for each learner as each learner's experience may be different (McLeod, 2003).

2.1.5 Minimal vs. explicit instructional methods

While there has been ongoing debate about the role learning theories play in instructional design (Christensen & Osguthorpe, 2004; Reigeluth, 1999; Wilson, 2005), there has also been discussion about the impact that instruction has on learning, with two arguments frequently presented

(Ausubel, 1964; Craig, 1956; Mayer, 2004; Shulman & Keisler, 1966). Some believe that all people (novices and experts) learn best when provided with instruction that contains unguided or partly guided segments. These ‘learners’ must discover or construct some or all of the essential information for themselves (Bruner, 1961; Papert, 1980; Steffe & Gale, 1995). On the other side are those who believe that, while experts often thrive without much guidance, nearly everyone else thrives when provided with full, explicit instructional guidance (Cronbach & Snow, 1977; David Klahr & Milena Nigam, 2004; Shulman & Keisler, 1966; Sweller, 2003).

This dichotomy was exacerbated by Kirschner, Sweller, and Clark (2006), who published an article on “why constructivist, discovery, problem-based, experiential, and inquiry-based teaching does not work”. This position built upon earlier assertions by Mayer (2004), who argued that discovery learning is not as effective as guided discovery.

The paper triggered considerable debate within the research community, particularly from supporters of constructivist approaches to learning. In their paper, Kirschner et al. (2006, p.76) argue that “minimal guidance during instruction is significantly less effective and efficient than guidance specifically designed to support the cognitive processing necessary for learning”. The central tenet of their argument is the view that constructivist approaches to learning are not supported by research and tend to ignore the key principles of cognitive science, because they overload learners’ working memory. According to Kirschner et al. (2006, p.77), the “aim of all instruction is to alter long-term memory. If nothing has changed in long-term memory, nothing has been learned”.

Student-centred learning (such as problem solving) places considerable demands on the learner’s working memory and, as this kind of learning is immediate, short-term and procedural, it does not help the student commit what they have learned to long-term memory (Kirschner et al., 2006). Without explicit and specific guidance, students exert an enormous amount of mental effort to make sense of the information that they are presented with, for example when solving a problem.

Solving a problem requires problem-solving searches, which must occur using limited working memory. This approach is an inefficient way of altering long-term memory because its function is to find a problem solution, not alter long-term memory. Indeed, problem-solving searches can function perfectly with no learning whatsoever (Kirschner et al., 2006).

It is also suggested that students who do not have a strong pre-existing knowledge about a topic will not be able to draw from their previous experiences to understand the new tasks presented to them (Kirschner et al., 2006). As a result, cognitive overload is more likely to occur (particularly in novice learners) because they lack the appropriate schemas to integrate the new information with their pre-existing knowledge. Without schemas, or scaffolding, information becomes confused, resulting in students becoming "lost and frustrated" (Kirschner et al., 2006, p.79).

The key conclusion from their argument is that students who are exposed to new topics and ideas should be given guidance in the form of direct instruction, which, they argue, results in greater learning than constructivist approaches. This view is reinforced by Clark, Kirschner, and Sweller (2012, p.6) who reaffirm their views that "decades of research clearly demonstrate that for novices, direct, explicit instruction is more effective and more efficient than partial guidance." They do, however, suggest that 'small group' activities and independent problems can be useful as a means of 'practicing' recently learnt content and skills.

A number of supporters of constructivism have provided counter-arguments to Kirschner et al. (2006). Suk Kim (2005) conducted a study of 76 sixth-grade students to determine the effectiveness of a constructivist teaching approach in elementary school mathematics. The study concluded that constructivist teaching is more effective in terms of academic achievement.

Hmelo-Silver et al. (2007) argue that many innovative teaching approaches, such as inquiry learning, are situated in problem-solving or constructivist contexts, in which learning is guided using scaffolding to reduce the students' cognitive load. Scaffolding means that learning tasks that are difficult and complex are more accessible and manageable for learners, and these pedagogies are supported by research. Research by Geier et al. (2008), cited by Hmelo-Silver et al. (2007, p.104), refers to one study involving over 19,000 middle-school science students who used inquiry-based instructional materials to achieve higher pass rates on standardised tests. The gains demonstrated by the students "occurred up to a year and a half after participation in the inquiry-based instruction".

Another study, by Lynch et al. (2005), included over 2000 eighth-grade students from ten middle schools in Maryland, USA. The findings of the results showed that students from each of the diversity groupings of limited language, socio-economic category, ethnicity and gender who had participated in the inquiry-based curriculum outperformed their respective comparison groups. These findings led Hmelo-Silver et al. (2007, p.104) to conclude that "there is growing evidence from large-scale experimental and quasi-experimental studies demonstrating that inquiry-based instruction results in significant learning gains in comparison to traditional instruction". Spiro and De Schryver (2009) add to the debate in the form of a book chapter in which they argue that the efficacy of constructivist, discovery, problem-based, experiential, and inquiry-based teaching depends on the content.

2.1.6 Directed (teacher-centred) vs constructivist (student-centred) models of instruction

It has been noted that the amount of guidance provided in a learning task should be well-balanced and tailored to "a student's knowledge and skills, which in turn vary across the different phases of the inquiry cycle and gradually increase during the learning process" (de Jong & Lazonder, 2014, p.382).

Existing instructional approaches can largely be classified in terms of the level of instructional control (de Jong & Lazonder, 2014). There are essentially two extremes – direct instruction at one end and open, learner-centred activities at the other.

Direct instruction approaches involve the learning content being explicitly offered to students through textbooks, lectures or teacher demonstrations (Kirschner et al., 2006). It is an explicit instructional method that was first formalised nearly fifty years ago by Siegfried Engelmann. Direct instruction is also referred to as explicit or instructivist teaching, and is a scripted, step-by-step approach to instruction. This approach stems from the work of Gagne (1985) who created practical instructional strategies for teachers by building on the early work of behavioural theorists (Pavlov, 1960; Skinner, 1938).

This style of instruction is teacher-directed and is well planned, with purposeful objectives established during the planning stage. Learners are instructed to make decisions about the content and sequence of the learning, with a finite body of knowledge broken down into component parts and then sequenced into a hierarchy ranging from simple to more complex (Malibar & Pountney, 2002). Essentially, the teacher is the authority providing direction while the learner is passive, explicitly following the instruction and absorbing the content (Lucas, 2002).

As noted by Engelmann (2014), this mode of teaching "emphasises well-developed and carefully planned lessons designed around small learning increments and clearly defined and prescribed teaching tasks" The teacher models the behaviour, provides practice and feedback and assesses whether the skill needs to re-taught (Ryder, Burton & Silberg, 2006). In this approach, there is a greater focus upon the interactions at play between the teachers and students.

Guided discovery approaches, in contrast, involve students generating their learning themselves from resources such as databases, investigations or laboratory experiments (see e.g. Bruner, 1961). This approach has its roots in constructivism, which harkens back to the work of Piaget et al. (1972). In the learning that takes place, "knowledge is more actively constructed by the learner and not passively received from the environment" (von Glasersfeld, 1989, p.162, citing the work of Piaget, 1973).

Guided discovery is more student-centred, with the learner being the central entity who must be actively engaged in seeking and constructing their own meaning. In this approach, students are not able to do anything they want, but rather are provided with some instruction by the teachers who arrange the activities. Students are then allowed to work with the resources provided to figure out the concepts, and the teacher is also able to present questions or problems to encourage the learners to make intuitive guesses (Schunk, 2008). This type of learning is thought to increase the ability of students to transfer information they construct to other areas, as it allows the students to independently explore broader issues (Klahr & Nigam, 2004).

In reviewing several decades of empirical evidence about discovery learning and direct instructional approaches, Lee and Anderson (2013, p.462) note that both positive and negative effects have been reported. Studies criticising discovery learning approaches have been mentioned above, including Kirschner et al. (2006) and Mayer (2004). Others have offered support for constructivist designs (Carpenter, Franke, Jacobs, Fennema & Empson, 1998; Cobb, Wood, Yackel, Nicholls & Wheatley, 1991; Hiebert & Wearne, 1996; Kamii & Dominick, 1998; Schwartz, Chase, Oppezzo & Chin, 2011).

These studies were conducted in a classroom, a setting in which “it is difficult to control all the factors at play” (Lee & Anderson, 2013, p.449). Some more focused laboratory studies showed that students could learn better in a discovery learning environment than in a direct instruction environment. These include Brunstein, Betts and Anderson (2009) and Dean and Kuhn (2007). While these studies show clear support for discovery learning approaches, there is no lack of studies showing the superiority of direct instruction in “many different domains” (Lee & Anderson, 2013, p.451). Studies in support of this approach go back over fifty years (see e.g. Chen & Klahr, 1999; Craig, 1956; Fay & Mayer, 1994; Gagne & Brown, 1961; Klahr & Nigam, 2004; Matlen & Klahr, 2010; Rittle-Johnson, Siegler & Wagner Alibali, 2001; Strand-Cary & Klahr, 2008; Tuovinen & Sweller, 1999).

Further support for direct instruction as an instructional approach comes from Hattie (2009), who synthesised over 800 meta-analyses (over 50,000 studies) relating to the influences on achievement in school-aged students. The findings presented the largest-ever collection of evidence-based research into what is effective in schools to improve learning. To quantify the overall effects from all the studies, Hattie converted the effects to a common measure (an effect size) so that they could be interpreted and compared.

Hattie examined 138 different influences on student achievement and the results were placed along a continuum of effect sizes, ranging from d=-0.34 to 1.44. One of the influences he investigated was direct instruction, which produced an effect size of 0.82, significantly greater than any other technique (apart from feedback) and double the average. Hattie described direct instruction as occurring in situations where “the teacher decides the learning intentions and success criteria, makes them transparent to the students, demonstrates them by modelling, evaluates if they understand what they have been told by checking for understanding, and re-telling them what they have told by tying it all together with closure” (Hattie, 2009, p.206).

Proponents of both direct instruction and guided discovery approaches claim their method to be the most valid under certain conditions – for example, the domain, students or classroom time (Dean & Kuhn, 2007; Klahr & Nigam, 2004). Kirschner et al. (2006) present arguments that direct instruction is more efficient than constructivist approaches to learning, contrary to the view upheld by, for example, Hmelo-Silver et al. (2007). While this debate is likely to continue, teachers will continue to use an array of teaching strategies given there is no single, universal approach that suits all situations (Bhowmik. Banerjee & Banerjee, 2013).

There is also consensus that contemporary learning approaches in geography should be active and engage students, utilising investigations and inquiry. Methods of instruction that adhere to this view include the geographical inquiry process, a sequence of steps that students follow to investigate geographically oriented questions and that will be explained in detail in section 2.2.3.

The educational effectiveness of this approach is often challenged by problems that become evident during the inquiry cycle. For example, students may find it challenging to develop a research question, investigate resources, interpret data and draw conclusions. Unguided discovery is, therefore, widely criticised (e.g. Mayer, 2004). Minimally guided approaches, such as inquiry-based learning, should be limited as they ignore human cognitive architecture and its structure and limitations (Kirschner et al., 2006) and place a heavy load on working memory (Sweller, 2005). In contrast, in well-guided instructional settings, students can embed new information into long-term memory (Hmelo-Silver et al., 2007).

Lee and Anderson (2013, p.446) ask “whether it is better to tell students what they need to know, or is it better to give students an opportunity to discover the knowledge for themselves?”. What is clear is that both approaches have their strengths and weaknesses. It is, however, difficult to find the right balance between the two extremes. This issue is called the “assistance dilemma” (Koedinger & Aleven, 2007) and refers to how educators must balance the information they provide within a learning environment. How best to achieve the balance between providing and withholding information remains a fundamental challenge in the development of instructional environments.

The contrast between direct instruction and constructivist approaches provides the starting point for this inquiry into GIS-based pedagogical approaches to learning. The methodological differences between the two approaches are clearly presented in Table 1.

Table 1. Methodological differences between directed and constructivist models of instruction
Source: adapted from Kirschner et al. (2006)

	Directed (Teacher-directed)	**Constructivist (Student-centred)**
Teacher roles	Transmitter of knowledge; Expert source; Director of skill/concept development through structured experiences.	Guide and facilitator as students generate their own knowledge; Collaborative resource and assistant as students explore topics.
Student roles	Receive information; Demonstrate competence; All students learn the same material.	Collaborate with others; Develop competence; Students may learn different material.
Curriculum characteristics	Based on skill and knowledge hierarchies; Skills taught one after the other in set sequence.	Based on projects that foster both higher level and lower level skills concurrently.
Learning goals	Stated in terms of mastery learning and behavioural competence in a scope and sequence.	Stated in terms of growth from where student began and increased ability to work independently and with others.
Types of activities	Lecture, demonstration, discussions, student practice, seatwork, testing.	Group projects, hands-on exploration, product development.
Assessment strategies	Written tests and development of products matched to objectives; All tests and products match set criteria; Same measures for all students.	Performance tests and products such as portfolios; Quality measured by rubrics and checklists; Measures may differ among students.
Other characteristics of directed learning and constructivist teaching and learning models	Focus on teaching sequences of skills that begin with lower level skills and build to higher level skills. Clearly state skill objectives with test items matched to them. Stress more individualised work than group work. Emphasise traditional teaching and assessment methods: lectures, skill worksheets, activities and tests with specified expected responses.	Focus on learning through posing problems, exploring possible answers, and developing products and presentations. Pursue global goals that specify general abilities such as problem-solving and research skills. Stress more group work than individualised work. Emphasise alternative learning and assessment methods: exploration of open-ended questions and scenarios, doing research & developing products; assessment by student portfolios, performance checklists, and tests with

		open-ended questions; and descriptive narratives written by teachers.

2.2 Developing student thinking skills

Fostering and engaging students' thinking skills is a central aim of education (Barak & Shakhman, 2008; Williams & Lahman, 2011). The development of critical thinking skills has also often been listed as the most important reason for formal education because "the ability to think critically is essential for success in the contemporary world where the rate at which new knowledge is created is rapidly accelerating" (Marin & Halpern, 2011, p.1).

Terms such as critical thinking, creative thinking and higher-order thinking have come to feature more prominently in the educational literature in recent decades (Beyer, 1988; Sternberg & Lubart, 1996; Zohar, 1999, 2006; Zohar & Dori, 2003), however, these terms can be difficult to define and some debate exists about their exact meaning (Barak & Shakhman, 2008, p.191).

2.2.1 What skills do students need in the 21st century?

Due to rapid economic and social change, schools are now expected to prepare students for "jobs that have not yet been created, technologies that have not yet been invented and problems that we don't yet know will arise" (Schleicher, 2010). Skills such as critical thinking and higher-order thinking, for example, are therefore considered to be an important consideration for educators (Gallagher, Hipkins & Zohar, 2012).

The importance of teaching critical thinking was highlighted by The Partnership for 21st Century Skills (P21) (2010). They identified six key elements of 21st century learning, with one specifically focusing on the need for students to know how to use their knowledge and skills "by thinking critically, applying knowledge to new situations, analysing information, comprehending new ideas, communicating, collaborating, solving problems, making decisions" (2002, p.3).

Further support for the teaching of critical thinking was provided by Burkhardt et al. (2003) in a report published by The Metiri Group and the North Central Regional Education Laboratory (NCREL). Additionally, the European Parliament and Council (2006) recommended eight key competencies of lifelong learning. While each competence is interdependent, there is an emphasis in each case on critical thinking, creativity, initiative, problem solving, risk assessment, decision taking and constructive management of feelings (EUR-Lex, 2011).

Other countries have also emphasised a similar focus and preferred student outcomes. Singapore, for example, acknowledges the importance of preparing students for a fast-changing world and has identified several 21st century competencies (Ministry of Education, 2014). These competencies are underpinned by a value system and delivered via a framework in all schools in Singapore. They include reference to 'Critical and Inventive Thinking'.

Responding to the challenges of the 21st century, which include environmental, social and economic pressures, requires young people to be creative, innovative, enterprising and adaptable, with the motivation, confidence and skills to use critical and creative thinking purposefully. This requirement puts considerable pressure on education systems and schools to effectively prepare students for work, citizenship and life beyond the classroom (Ministry of Education, 2014).

The newly developed Australian Curriculum developed by ACARA has been produced against a set of consistent national standards designed to improve learning outcomes for students in the country. These standards are the basis of "future learning, growth and active participation in the Australian community" (ACARA, 2013). In the curriculum, 21st century skills are noted as a priority and they are listed as 'general capabilities'. Underpinning the new curriculum is the Melbourne Declaration on Educational Goals for Young Australians (MCEETYA, 2008), in which these 21st century skills were highlighted.

2.2.2 The development of higher-order thinking skills

In the early part of the 20th century, the primary role of teachers was typically to transmit information to students using traditional approaches aligned with behaviourist theories (Bransford, Brown & Cocking, 2000). The focus then was largely on the acquisition of basic literacy skills such as reading, writing and calculating (Zohar & Dori, 2003). Up until the 1970s, learning was considered linear and sequential with complex understanding thought to occur only by the accumulation of basic, prerequisite learning (Bransford et al., 2000; Zohar, Degani & Vaaknin, 2001). Only those students who had mastered the lower levels could progress to higher cognitive stages and therefore many low-ability students were left to dwell in lower order thinking levels because they had not mastered the basic level of understanding (Bloom, 1956; Gagne, 1974). It was a not-uncommon view among educators that the instruction required to produce thinking skills was appropriate only for a certain section of the student population, specifically high-achieving learners; however, thinking should be applied to all learning and to all learners (Zohar & Dori, 2003). This traditional view suggests that only a select few were able to enjoy the privilege of an educational tradition that fostered their thinking (Bransford et al., 2000).

The teaching of 'thinking skills' is a more recent emphasis and is an expression used to refer to pedagogic approaches through which "specific strategies and procedures may be taught and used by learners in a controlled, conscious way to make their learning more effective" (Moseley et al., 2005, p.24). Fundamental to the learning process, thinking skills combine both cognitive processes and the ability to complete a given task (Milvain, 2008). They refer to an intellectual process involving the formation of concepts, analysis, application, syntax, and evaluation of information that is collected or observed, experienced or reflected upon by an individual (Ball & Garton, 2005). To support the teaching of thinking skills, many school practices and policies are built on the assumption that students learn best when the curriculum is well matched to students' learning abilities. This assumption is based on the belief that when students understand what they are being taught, they are more likely to be actively involved in the learning process and less likely to disengage from classroom instruction (Hallinan, Bottoms, Pallas & Palla, 2003).

In contemporary educational settings, there are frequent calls to integrate higher-order thinking skills more effectively in curricula including content thinking, critical thinking and creative thinking (Barnett & Francis, 2012; Crawford and Brown, 2002; Fischer, Bol & Pribesh, 2011; Wagner, Baum & Newbill, 2014). Higher-order thinking skills are the highest level in the hierarchy of cognitive processes. They are developed when new information is acquired and retained, compiled, linked to existing knowledge and then used in a way to achieve a goal or solve a complicated situation (Yee, Yunos, Othmanc, Hassand, Tee & Mohamad, 2015). Higher-order thinking skills are activated when individuals encounter unfamiliar problems, uncertainties, questions or dilemmas (King, Goodson & Rohani, 1998) and different approaches to instruction can contribute to the development of higher-order thinking (Angeli & Valanides, 2009) including problem-based and inquiry-based learning, project-based learning and simulations (Benner, Sutphen, Leonard & Day, 2010; Glasgow, Dunphy & Mainous, 2010; Nilson, 2010).

Many educators support the argument that students have a significant advantage if they can incorporate higher-order thinking skills when problem solving and developing understanding; however, most students need to be encouraged, taught and assisted in developing higher-order thinking processes (Heong et al., 2011). Several authors, including Zohar and Dori (2003), have informed discussion in this area and in one study identified that low-achieving students are overly challenged and thus frustrated by teaching that includes activities focused on higher-order thinking. Motivated by observations made during teachers' professional development workshops, they presented four studies whose objective was to teach higher-order thinking in science classrooms. It was found that by the end of the four programmes, students with high academic ability gained higher thinking results compared to their peers of low ability. Students from both groups were found to have achieved considerable progress with respect to their initial results and their findings strongly indicate that teachers should encourage students of all academic levels to engage in learning activities that involve higher-order thinking skills. It was also noted that teachers' attitudes towards instruction in higher-order thinking skills were generally favourable; however, many teachers expressed the view that low-achieving students were unable to deal with tasks that require [higher-order] thinking skills (Zohar & Dori, 2003).

Other researchers (e.g. Raudenbush, Rowan & Cheong, 1993; Zohar et al., 2001) have shown that teachers involved in programmes that target a more 'general' school population, in terms of socio-economic background and academic ability, often tend to engage low-achieving students less than high-achieving ones in thinking activities. These findings support early work by Peterson (1988) and Newmann (1990). White and Frederiksen (1998, 2000) showed that a special curriculum designed to teach physics and inquiry was particularly beneficial for low-achieving students.

New and contemporary approaches, however, emphasise 'learning with understanding', which highlights the importance of not just remembering and repeating information but being able to use it effectively (Bransford et al., 2000; Zohar & Dori, 2003). Contemporary teaching and learning approaches tightly link thinking with understanding, and "the ability to perform in a flexible, thought-demanding way is a constant requirement" (Perkins & Unger, 1999, p.97). There are, however, varying perspectives on how best to achieve learning to think critically. Despite the acknowledged importance of developing students' higher-order thinking skills, as highlighted by the research above, there appears to be a lack of empirical studies that focus on the development of critical thinking at the high-school level (Marin & Halpern, 2011). As such, it is intended that this study will contribute to the limited research that exists in this space.

2.2.3 The geographical inquiry process

Over the past few decades, an emphasis has been placed on the development of inquiry skills and there has been a move towards inquiry-based learning, or IBL (Bryant & Favier, 2015).

> Inquiry is an approach to learning whereby students find and use a variety of sources of information and ideas to increase their understanding of a problem, topic or issue of importance. It requires more than simply answering questions or getting a right answer. It espouses investigation, exploration, search, quest, research, pursuit and study. It is enhanced by involvement with a community of learners, each learning from the other in social interaction. (Kuklthau, Maniotes & Caspari, 2007, p.2)

It is argued that GIS as a tool is well-placed to support geographical learning through inquiry as it allows "teachers to design projects in which students explore spatial problems with digital maps, formulate questions about those problems, collect geodata in the field, visualise and analyse geodata in maps, and use these maps to answer their questions" (Bryant & Favier, 2015, p.128).

Inquiry learning is a form of student-centred learning in which "students actively construct or build new ideas or concepts based upon past knowledge or experience" (Ari, 2011, p.768). There are numerous examples in the literature of teachers using inquiry-based approaches when teaching with GIS (Demirci, Karaburun & Ünlü, 2013; Favier & van der Schee, 2012; Milson, Demirci & Kerski, 2012) and it is argued that such an approach aids progression in students' geographic knowledge and skills (geographic literacy) and motivation to learn about how to problem solve (geographic drive) (Bryant & Favier, 2015).

Other inquiry approaches include problem-based learning, which has also been used to integrate geospatial technologies (such as GIS) according to Doering and Veletsianos (2007b, p.108). It has been argued by some, however, that there is a lack of both "technological and pedagogical knowledge on the part of teachers employing it" (Doering, 2004; Doering, Hughes & Huffman, 2003).

Geographic inquiry is a mode of thinking like other research-oriented approaches, such as scientific method; however, it incorporates a spatial dimension and has a geographical or locational context to the process. According to the Environmental Systems Research Institute (ESRI), understanding how location influences the characteristics and relationships of certain phenomena, is the foundation of geographic thinking. The steps of geographic inquiry are as follows and can be visualised in Figure 4.

1. Ask a geographic question
2. Acquire geographic resources
3. Explore geographic data
4. Analyse geographic information
5. Act on geographic knowledge (Environmental Systems Research Institute (ESRI), 2003).

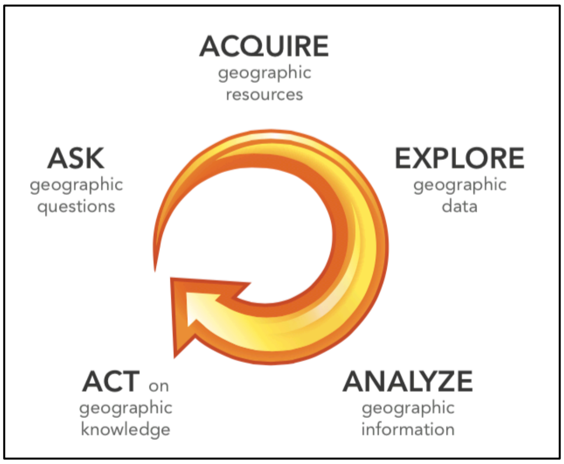


Figure 4. The Geographic Inquiry Process

(Source: Environmental Systems Research Institute (ESRI) Schools & Libraries Program, 2003)

The questions that geographers ask are one of the characteristic features of the discipline, as they "frame the way that Geographers look at the world: they influence how geographical knowledge is constructed" (Roberts, 2003, p.37). Neighbour (1992, p.15) identified five core questions when considering geography. They include:

1. What is the phenomenon?
2. Where is it located?
3. Why is it located there?
4. What impact does its location have?
5. What changes should be made? What ought to be done?

While Neighbour's five questions are not listed per se in the Australian National Geography curriculum, they are implicit in the rationale provided in the curriculum documentation.

> Geographical Inquiry is a process by which students learn about and deepen their understanding of geography. It involves individual or group investigations that start with geographical questions and proceed through the collection, evaluation, analysis and interpretation of information to the development of conclusions and proposals for actions. Inquiries may vary in scale and geographical context. (ACARA, 2013)

An inquiry-based approach to learning recognises that knowledge is generated in the "process of answering questions" (Roberts, 2003, p.39). Questioning techniques have always been an important part of geographical inquiry, with Naish, Rawling and Hart (1987, p.36) stating that the starting point for inquiry was "necessarily a question, problem or issue". Inquiry-based approaches to learning are, therefore, consistent with constructivist theories of learning because of the emphasis they place on thinking and understanding, rather than on memorisation. The process of inquiry seeks to achieve broader educational outcomes through investigation of studies that are 'relevant to students' present and future lives. The planning of inquiry means that those engaged with the process are making judgements, which are relevant in different contexts.

2.2.4 Geographical inquiry and the development of thinking skills

Geographical inquiry is a process that students can follow themselves as they develop the skills of asking questions, selecting sources of evidence, analysing and evaluating data, and reaching conclusions (Roberts, 2003). As students engage in this process, they are essentially following a 'progression' characterised by increasing the:

- complexity of the context of inquiry;
- involvement of students in the planning of enquiries (suggesting questions and issues to be investigated, planning sequences of investigation);
- involvement of students in selection (of sources, skills and ways of presenting data);
- ability to use a range of skills (presenting and analysing data, reaching conclusions); and
- ability to be critical in evaluating sources and evidence (Roberts, 2003, p.12).

By following this progression, students generate interest in the topic and then, using data, make connections to other ideas by applying different thinking skills. The final step in the process is for students to reflect on their learning, which results in them being able to think critically about the topic learnt. The nature of this process means that in the latter stages of the inquiry, students are using higher-order thinking skills to engage in critical thought about topics in different contexts and situations.

Further support for this assertion is provided Table 2, which correlates various thinking skills with different aspects of inquiry.

Table 2. Types of thinking involved in learning through inquiry
Source: Roberts (2003, p.45)

Aspect of Inquiry	**Thinking Skills**
Needing to know	Pose and define questions Generate ideas Suggest hypotheses Plan what to do and how to research
Using data	Locate and collect relevant information Sort Classify Sequence
Making sense of data	Compare Contrast Draw inferences Make judgements and decisions
Reflecting on learning	Evaluate information Explain thinking Look for alternative innovative outcomes Develop criteria for judging the value of their own and others' work

The link between geographic inquiry and Geographic Information Systems will be explored in Section 2.2.5.

2.2.5 The link between Geographic Information Systems (GIS) and geographic inquiry

It has been suggested that GIS is an interdisciplinary technology that supports high-level thinking and is considered appropriate to inquiry and open-ended investigations, as well as complex real-world problems (Henry & Semple, 2012). Engaging in learning such as this "supports the open expression of ideas, provides active modelling of thinking processes, develops thinking skills, and motivates students to learn" (King et al., 1998, p.43).

Within a GIS-based learning environment, students start the geographic inquiry process by formulating geographic questions or hypotheses, often associated with problems or issues. They can access knowledge and geographic data from multiple sources, present geographic data and information in forms of maps, images, tables, and charts, explore the data through carefully constructed queries, and analyse the data to draw conclusions. Critical thinking skills are consequently enhanced. In this way, students develop a wide variety of skills, including analytical skills, critical thinking skills, communication skills, and inquiry skills (Audet & Ludwig, 2000; Demirci et al., 2013; Favier & van der Schee, 2012; Kerski, 2003; Milson et al., 2012).

The characteristics of GIS-based instruction enable teachers to develop approaches that seek to "stimulate geospatial relational thinking skills that are often difficult to address" (Favier & van der Schee, 2014, p.228). Their design is quite different to more traditional lessons (as they are learner-centred) and, as a result, have the potential to change the way that teaching and learning are conducted in the classroom (Baker & White, 2003; Kerski, 2003; Sinton & Lund, 2007).

A key strength of GIS-based instruction is the ability to incorporate it within fieldwork, which is important in helping students critically understand and appreciate the world around them. GIS-based questions form the basis of the investigation in the same way that a topic or issue forms the first stage of inquiry; this typically involves students collecting and analysing data to explore any relationships that may exist.

Kerski (2015) notes that GIS-based investigations are often "value-laden and involve critical thinking skills", with students, for example, "investigating relationship between altitude, latitude, climate, and cotton production". GIS-based inquiry provides an opportunity for students to put forward recommendations based on the results of their investigation, which can lead to further investigation ideas, and thus the cycle of geographic inquiry continues.

The Geography Education Standards Project, as cited by Houtsonen (2006, p.25), identified five generic questions that can be answered using a GIS (Table 3).

Table 3. The questions and types of tasks that a GIS can assist with (Geography Education Standards Project, 1994b)

Question	Type of Task
1 – What is at...?	Inventory and/or monitoring
2 – Where is...?	Inventory and/or monitoring
3 – What has changed since...?	Inventory and/or monitoring
4 – What spatial patterns exist...?	Spatial Analysis
5 – What if...?	Modelling

The Geographic Information Technology Training Alliance (2010) also produced a similar set of questions, as outlined below in Table 4.

Table 4. GIS Tasks: Answering Questions
(Geographic Information Technology Training Alliance, 2010)

Task/Object	**Question**
Locations	What is at a given location or where is a specific item located?
Trends	What has changed since…?
Patterns	What spatial patterns exist?
Networks	How to get to…?
Modelling	How would it happen?
Decisions	What should one do if…?

Tables 3 and 4 show a progression of questions that increase in their complexity. These correlate with the deeper thinking level evidenced in the geographic inquiry process. GIS and geographic inquiry are, therefore, complementary processes because a GIS models and assists students to structure their investigations (Geographic Information Technology Training Alliance (GITTA), 2010).

Some authors argue that GIS-based instruction is aligned with constructivist influences (for instance, Johansson and Kaivola, 2004). Houtsonen (2006) adds that GIS-based instruction can be delivered in a way that is consistent with the central tenets of constructivist learning, making three assertions:

1. GIS teaching leads pupils to make their own geographical observations instead of reading about those made by others and introduces them to many topics that lie at the very heart of geography.

2. They can improve their cartographic skills, learn to interpret natural and cultural landscapes and attempt to perceive interaction relations between phenomena.

3. GIS teaching also allows them to develop their skills in influencing decisions made within society opening opportunities for them to take an active part in developing their own community.

Bednarz (1995) aligns the characteristics of GIS teaching with those of constructivism as shown below in Table 5. The information presented in the table suggests that GIS-based instruction can be developed using constructivist principles. If this occurs, "students are active participants in the learning task, they are engaging collaboratively with other students and reflecting upon real-world situations" (Jonassen, 1996, p.65).

Table 5. Comparing GIS with constructivism
(Source: Bednarz, 1995)

Characteristics of Constructivism	**Characteristics of GIS**
Students construct knowledge.	Students construct knowledge through building databases or maps.
Students discover relationships through experience.	Students explore spatial relationships through mapping.
Students learn in complex, authentic situations.	Students learn from real-world data and places.
Students manage their own learning.	Students guide themselves and identify relationships by exploring data.
The process of learning is as important as the product.	GIS is a tool to explore.

As noted in Section 1.5, GIS has been identified as an educational technology that can enhance students' geographical understanding; however, there are few studies that focus specifically on the nature of GIS-based instruction, despite several researchers having acknowledged this need (Bednarz, 2004; Goldstein and Alibrandi, 2013). Kemp, Goodchild, and Dodson (1992) made one of the earliest references to pedagogical questions about GIS when they distinguished learning *about* GIS from learning *with* GIS. Sui (1995) followed soon after by categorising the use of GIS-based education in two ways, and from the perspective of a teacher, by distinguishing between *teaching about* GIS from *teaching with* GIS.

Teaching *about* GIS implies that the technology is peripheral to intellectual cores of geography and other disciplines, and is, therefore, taught as a technical field with a collection of marketable skills. Teaching *with* GIS stresses geographic concepts and using the tool to solve geographic problems in a variety of disciplines. While the distinction between *teaching about* GIS and *teaching with* GIS may be obvious, there appears to be a lack of guidance about how GIS can be effectively embedded within an instructional framework for use in a classroom context.

While there are some studies showing significantly higher achievement for lessons undertaken using GIS (Baker & White, 2003; Goldstein & Alibrandi, 2013; Lee & Bednarz, 2009), there has been little research undertaken on how to teach GIS in a way that ensures students are able to "analyse and reason about the challenges in the world around us" (Favier & van der Schee, 2014, p.228). Some authors (Kim, M. Kim, K. & Lee, 2013; Marsh et al., 2007) have also called for GIS software to be 'minimalist' in its design so that the pedagogical potential of GIS can be realised.

2.2.6 Aligning geographic inquiry with Bloom's revised taxonomy

For over fifty years, *Taxonomy of Educational Objectives, The Classification of Educational Goal, Handbook 1: Cognitive Domain* (Bloom, 1956), has influenced educational theory and practice. Commonly referred to as 'Bloom's Taxonomy', after lead author Benjamin Bloom, it has been "used by educators in virtually every subject area at virtually every grade level" (Marzano & Kendall, 2007, p.1).

The taxonomy offers a straightforward way to classify instructional activities as they advance in difficulty (Duron, Limbach & Waugh, 2006, p.160), with educators able to arrange learning tasks in hierarchical order from less to more complex. In each of these domains, lower levels provide the basis for higher levels of learning. The levels succeed one another, and one level must be mastered before the next can be reached. The taxonomy's original levels as published were – in ascending order – *Knowledge*, *Comprehension*, *Application*, *Analysis*, *Synthesis* and *Evaluation*.

In 2000–2001, one of the original authors of the taxonomy and a former student of Bloom's led a group to revise the cognitive taxonomy. During five years from 1995 to 2000, Anderson and Krathwohl co-chaired a group of educators and researchers to enhance Bloom's original taxonomy. They focused on creating a revised taxonomy, which also included a hierarchical framework that requires achievement of the appropriate skill or ability before progressing to the next, more complex level. At the simplest level, *Remembering* requires an answer that demonstrates a simple recall of information. The most complex task, *Creating*, requires the generation of new ideas, products or ways of viewing things (Anderson & Krathwohl, 2001).

In this study, and based on the revised taxonomy of learning, lower-order thinking skills operate at three levels: *remember*, *understand* and *apply*. It is also possible to see higher-order thinking skills operating at three levels: *analyse*, *evaluate* and *create*. Table 6 provides definitions for each of the categories in the cognitive process dimension.

Table 6. Definitions of categories in the Cognitive Process Dimension
(Anderson & Krathwohl, 2001)

Cognitive Process Category	**Definition**
Remember	Retrieve relevant knowledge from long-term memory.
Understand	Construct meaning from instructional messages, including oral, written and graphic communication.
Apply	Carry out or use a procedure in each situation.
Analyse	Break material into its constituent parts and determine how the parts relate to one another and to an overall structure or purpose.
Evaluate	Make judgements based on criteria and standards.
Create	Put elements together to form a coherent or functional whole; reorganise elements into a new pattern or structure.

Compared with the original taxonomy, the revised taxonomy includes several key differences. Firstly, the type of terminology used has changed, as the nouns in each of the six categories have been replaced by verbs. Also, the revised taxonomy has been developed into a two-dimensional table, with a Knowledge Dimension and a Cognitive Process Dimension. The revised taxonomy is clearly differentiated from the 1956 model, as the cognitive processes can be easily documented and tracked, making it easier for teachers to conduct assessment, their own self-assessment as well as student assessment (Wilson, 2013) – although its "impact in curriculum planning, examining and research has been greater than its active use by teachers" (Moseley et al., 2005, p.54).

GIS is a technology that can complement Bloom's revised taxonomy and learning activities that utilise geographical inquiry (West, 2003). By adopting an inquiry-based approach, students develop critical and creative thinking skills using approaches that enable them to think logically (using evidence), testing explanations and analysing arguments. In doing so, they think "deeply about questions that do not have straightforward answers" (ACARA, 2013). Therefore, when the geographic inquiry approach provides the framework for a GIS-based inquiry, the types of questions presented in Tables 2 and 3 can be applied. In doing so, it is possible to perceive that increasingly sophisticated GIS tasks could lead to the development of thinking skills at different cognitive levels and increasing complexity.

Numerous studies drawing on Anderson and Krathwohls' revised taxonomy have been undertaken in education. Examples include Näsström (2009), who compared teacher and assessment expert standards, and Noble (2004), who investigated curriculum differentiation and multiple intelligences using the revised taxonomy. Other studies include those of Bümen (2007), who observed the effective of the original taxonomy versus the revised taxonomy on lesson planning skills, and Hanna (2007), who explored the implications for music education using the revised taxonomy.

Other GIS-based studies have adopted Anderson and Krathwohl's (2001) revision of Bloom's taxonomy of educational objectives. As noted previously, a study evaluating problem-based learning (PBL) using GIS technology was undertaken in a Singapore secondary school (Liu, Bui, Chang & Lossman, 2010). Adopting a quasi-experimental research design, the study used the taxonomy as criteria to evaluate students' cognitive learning skills. Tests were carried out using an experimental group subjected to PBL using GIS and a control group subjected to PBL but without GIS. The results reported significant differences in learning outcomes between the two groups, and the conclusion was that learning with PBL-GIS pedagogy can result in higher-order learning outcomes.

There are, however, some limitations in the study of Liu et al. (2010). Firstly, the pre-test questions did not appear to relate to lower- or higher-order thinking but rather general aptitude. It was indicated that the control group had not previously used GIS and the experimental group had; therefore, it is questionable whether it is possible to compare the two groups on the basis that prior knowledge may have influenced the results. In addition, the pre- and post-test activities were different in their format and it could be argued that it is not possible to compare the amount of pre-/post-test improvement recorded. The analysis of the pre-test results showed a statistically significant difference at the Apply level before the lessons started, and there were also very low scores on some levels – for example, evaluate and create – which suggests that flaws in the design of the instrument meant it was not possible to detect improvement at these levels.

This study will use rigorous methods corresponding to Anderson and Krathwol's (2001) revision of Bloom's (1956) taxonomy to focus attention on the development of students' higher-order thinking skills using GIS technology.

2.3 The role of scaffolding to support learning

The efficacy of engaging students in the learning process has been explored (Marzano, 2003) and the benefits of doing so have been noted previously. One of the benefits of adopting an active learning approach compared to more didactic instruction is that traditional lecture-driven instruction may result in knowledge being overly contextualised and the transfer of knowledge may not take place. As a result, a strong emphasis has been placed on the support that students need during teaching and learning in order to be able to apply skills and understanding to new situations (Carlson, 2008). One way of achieving this is by matching the cognitive requirements of the instructional activity to the students' cognitive abilities, a process referred to by Vygotsky (1978) as the *zone of proximal development*.

Progressively changing the learning process to suit the needs of the learner has been referred to as scaffolding instruction (Hmelo-Silver et al., 2007). This concept is derived from the socio-constructivist model of learning proposed by Vygotsky (1978) and was first described by Wood, Bruner, and Ross (1976, p.90), who defined it as "a process that enables a child or novice to solve a problem, carry out a task or achieve a goal which would be beyond his unassisted efforts". Multiple definitions exist, including "tools that help students perform a learning process by supporting the dynamics of the activities involved," (de Jong & Lazonder, 2014, p.377). Another refers to an instructional scaffold as "a tool for enculturating students into the thinking patterns of experts" (Hogan, 1997, p.2). They are a pedagogical support that experts use to help learners perform tasks they cannot do themselves (Hmelo-Silver et al., 2007) and they can also be used as a cognitive or motivational support "to help learners realise their potential" (Lajoie, 2014, p.628).

As a construct, the notion of scaffolding was originally designed to characterise how more experienced peers (or adults) can assist learners (Reiser, 2004, p.274). It was believed that learning occurred in one-on-one interactions in which more knowledgeable people guide the learner (Raes, Schellens, Wever & Vanderhoven, 2012, p.84).

Scaffolding, as described above, is based upon the idea of providing supportive assistance to the learner within the parameters of a learner's zone of proximal development (or ZPD) (Wood et al., 1976). This notion is supported by Marshall & Horton (2011, p.93), who note that scaffolds can assist students to work in the zone of proximal development where they are "challenged to think critically without being overwhelmed". ZPD is a measure of a learner's current ability and knowledge, i.e. what he/she can perform with no assistance, and the learner's ability and knowledge, or what the learner can be challenged to accomplish with supportive assistance (Vygotsky, 1978).

Vygotsky (1978, p.78) defined ZPD as

> the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers.

It was noted by Vygotsky that interaction with peers presented an effective way of developing skills and strategies. These 'strategies' could, with the support of teachers or more skilful peers, help students to work with the 'zone of proximal development', which would provide them with the appropriate stimulus to achieve the task.

Others, including Aaron Doering and Veletsianos (2007b, p.109), refer to the ZPD as "a support that a teacher or learning environment provides to a learner to assist him or her in a range of cognitive tasks, from the understanding of a task and mastering of a skill to the solving of a problem".

In contemporary classrooms, the scaffolding metaphor is used widely to describe various types of support and contexts of interaction (Tabak, 2004), and there exists an extensive body of research on scaffold-based learning in inquiry- and problem-based environments (Collins, Brown & Newman, 1989; Davis & Linn, 2000; Golan, Kyza, Reiser & Edelson, 2002; Reiser, 2004).

Scaffolding is seen as providing significant benefit to learners, enabling them to engage in complex tasks that would "otherwise be beyond their current abilities" (Hmelo-Silver et al., 2007, p.100). "It can be a cognitive support for problem solving or motivational support to help learners realise their potential" (Lajoie, 2014, p.628). When the learning task is too difficult, experts can model the task; as students become competent and confident, scaffolding is gradually lessened so that students become independent learners (Azevedo & Hadwin, 2005; Lajoie, 2005; Pea, 2004).

Amidst the literature that focuses on the role of GIS as a tool to support geography education, a study by Doering (2004) examined three online pedagogical models for integrating GIS in preservice teacher courses found that learning with geospatial technologies is best accomplished using multiple scaffolds and guidance in structured problem solving, as it provided students with guided practice along with expert assistance. In a further study, Doering and Veletsianos (2007b) examined how students utilise a multi-scaffolding environment (MSE) while using GIS to solve geographic problems, and the relationships between the scaffolds used and students' cognitive load and problem-solving ability.

Four different scaffolds were adopted in the Doering and Veletsianos (2007b) study – situated movies, screen-capture videos, conversational agents and collaboration zones. Of relevance to this study are two of these: screen-capture videos and collaboration zones. Screen-capture videos were used to demonstrate how to effectively use GIS to solve the authentic problems posed in the situated video, and in one section of the screen-capture video it specifically explained how to use specific GIS tools. The fourth scaffold, the collaboration zone, allowed learners to engage with their peers and discuss the problem. Both these approaches were identified as being relevant scaffolds to support student learning outcomes in this research.

The results of the study suggest that this may assist learners as they became familiar with using the 'tool' and "as such, screen-capture videos may be a viable scaffold in assisting learners in becoming competent in the use of the tool" (Doering & Veletsianos, 2007b, p.124). Further, the qualitative results indicate that the most frequently accessed scaffold was the collaboration zone. They show that "social interaction and collaborative work were valued more highly than the rest of the scaffolds" (p.125). Johnson and Johnson (2004) have also previously examined the merits of engaging in collaborative work to solve a task, as well as the roles that learners take in supporting each other.

Building upon this research, this study will also investigate how scaffolding can be used to support learning outcomes. In contrast to the work of Doering and Veletsianos (2007b), however, which focused on the learner-centred approach of problem-based learning, this study will examine how different forms of scaffolding can enhance thinking skills within different pedagogical approaches – direct instruction and guided discovery.

Another study by Brickell and Herrington (2006) explored the design of a real-world geographic problem, embedded within a web environment supported by traditional fieldwork. Of relevance to this study is the fact that the learning task used scaffolding prompts and supports embedded within the environment to facilitate student learning. The paper describes the theoretical foundations for the approach, the design of the learning task, and specific approaches used in the environment. The study also draws on what Brush and Saye (2002) refer to as 'soft scaffolds' – specific support provided by a teacher or peer group member; and 'hard scaffolds' – embedded support within the online environment (see the next section for further discussion). The scaffolds prompt the students as they reflect and review their actions and, in doing so, provide the "bridge between the learner's existing cognitive processes and the additional cognitive demands required in understanding the interactions and interrelationships of the problem space" (Brickell & Herrington, 2006, p.539). The online tools or 'hard scaffolds' act as 'metacognitive coaches', providing hints to assist the learner to develop skills that better facilitate transfer across domains.

2.3.1 Soft and hard scaffolds

Scaffolds appear in a variety of forms. Brush and Saye (2002) classify scaffolding techniques as being either *soft* or *hard*.

Soft scaffolds are dynamic and relate specifically to the actions provided by a teacher to support the learner when they require it (Brush & Saye, 2002; Roehler & Cantlon, 1997). This support can occur as the teacher circulates around the room, directs questions or provides feedback on student progress (Simons, Klein & Brush, 2004). They are spontaneous and instantaneous support to improve the students' learning processes (e.g. Azevedo, Cromley & Seibert, 2004). Soft scaffolds can also be provided by peers, and to that extent student–student interactions are also acknowledged as being a form of soft scaffolding, particularly in game-based learning approaches (Chen & Law, 2015).

Hard scaffolds are different in that they are static supports that are (normally) developed in advance based on difficulties that are anticipated to develop at some stage during the learning process (Brush & Saye, 2002). Hard scaffolds frequently use technology and are static, which means they are not necessarily adaptable to a student's learning needs (Chen & Law, 2015). A variety of research on hard scaffolds has has yielded mixed results (e.g. Demetriadis, Papadopoulos, Stamelos & Fischer, 2008; Papadopoulos, Demetriadis, Stamelos & Tsoukalas, 2009; Vreman-de Olde & de Jong, 2006).

Hannafin, Land, and Oliver (1999) also refer to two specific types of hard scaffolds, *conceptual* and *strategic*. Conceptual scaffolds guide the learner throughout a problem-solving process through hints or clues. Strategic scaffolds provide support to assist the learner, for example, to analyse a task. This support could be in the form of video or screencasts, as was the case in this research.

Renewed interested in technology-based scaffolds has been evident in education research (Kim & Hannafin, 2011; Raes et al., 2012). Several technological advances have facilitated this engagement – for example, cognitive technologies (Pea, 1985), technologies of the mind (Salomon, Perkins & Globerson, 1991) and mind tools (Jonassen, 2000). Research in these areas has also provided the opportunity to "scaffold students' critical thinking and problem solving" (Kim & Hannafin, 2011, p.403). While the use of ICT as a scaffold is of considerable interest, it is different to traditional learning environments as they rely on computers to enhance the learning experience (Sharma & Hannafin, 2007). The design of effective scaffolds that use technology is very important and requires careful understanding of a "learner's ability to interact with and use scaffolding tools" (Sharma & Hannafin, 2007, p.27).

2.3.2 Designing cognitively efficient scaffolds

When seeking to assist students to understand the content and concepts of a learning task, it is possible to use scaffolds to support them (Kollar & Fischer, 2006). This support is particularly important in activities that are computer-based, as the greater cognitive demands of these environments may increase the chance of cognitive overload in the learner (Lee, Plass & Homer, 2006). It is, nevertheless, a viable strategy to use scaffolds to capture and focus a learner's attention during tasks that are either confusing or challenging.

Cognitive load theory (CLT) is a general theory for instructional design and is based on research into human cognitive architecture (Paas & Sweller, 2014; Sweller, Ayres & Kalyuga, 2011). Three types of loads occur: extraneous load (due to the processing of unnecessary information); intrinsic cognitive load (due to the complexity of the learning materials); and germane load (caused by processing relating to learning). A person's capacity for this combined load is fixed and cognitive overload can be a problem for some learners, particularly in computer-based environments (Mayer, Heiser & Lonn, 2001). In simple terms, the assumption is that too much cognitive load limits learning because of the limited capacity of working memory (Ayres, 2015).

Cognitive load theory (CLT) is grounded in "well-established memory research" (Ayres, 2015, p.632). CLT uses the three-component model of sensory memory, working memory and long-term memory and it is assumed that learning requires conscious processing of information in the limited capacity provided by working memory. Specific instructional strategies can be used to reduce the extraneous load and develop the germane load so that learners can more effectively use their cognitive resources. Any form of support that assists a learner develop a new level of understanding can be used to control the cognitive load constraints on an individual and help them to support the creation of schema that allows them to achieve a higher level of performance (Lajoie, 2005).

GIS-based instruction is partly supported in this study by multimedia scaffolds designed to help reduce the cognitive load by carefully outlining the skill required to complete the task.

2.3.3 Implementing effective scaffolds

When students do not have the sufficient knowledge to develop their own inquiry, information can be ordered for them during the learning process using scaffolds (Hmelo-Silver & Azevedo, 2006; Sharma & Hannafin, 2007). Once this data has been observed, students are then able to explore it further with a reduced level of support (Hmelo-Silver et al., 2007).

Some authors have developed empirically based design guidelines for incorporating effective scaffolding strategies to support learning (Hmelo & Guzdial, 1996; Hmelo-Silver, 2006; Quintana et al., 2004; Reiser et al., 2001). When promoting motivation and engagement during problem-based learning, for example, scaffolds should "establish task value, promote mastery goals, provide for social interaction, promote emotion regulation, promote expectancy for success, and promote autonomy" (Belland, Kim & Hannafin, 2013).

Several authors also state that scaffolds, which provide students with choice about learning tasks, can increase interest (e.g. Palmer, 2009; Patall, 2013). Specific and focused questions can also be used to engage student interest and stimulate students' curiosity (Krajcik, McNeill & Reiser, 2008). Additionally, using language similar to learners' everyday experiences can also engage student interest in a learning task (Rotgans & Schmidt, 2011).

Others, including Reid, Zhang, and Chen (2003), organise the level of scaffolding support according to the typology of inquiry learning processes, e.g. interpretative support, experimental support and reflective support. Quintana et al. (2004) group the amount of guidance provided according to the learning processes supported, i.e. sense-making, process management, and articulation and reflection.

Hogan and Pressley (1997) conducted a detailed study of scaffold-related literature and identified eight elements of scaffolded instruction. These include:

- the need for teachers to consider curriculum goals and student needs when selecting appropriate tasks;
- establishing a shared goal, as students may be more motivated to learn when the teacher works with them to develop instructional objectives;
- diagnosing student needs using knowledge about the students' background understanding and misconceptions;
- providing bespoke assistance for students, such as prompting, modelling, telling or discussing, and adjusting as needed;
- asking questions, as well as offering praise and encouragement, to help students maintain a focus on their goals;
- providing feedback and helping students learn to monitor their own progress;
- working to create a learning environment in which students feel able to take risks with their learning; and

- helping students to be less dependent on the teacher's extrinsic signals, which assists them to be independent in other contexts.

2.3.4 Multimedia learning

Traditional teacher-led instruction is no longer widely advocated by educationalists and there is a movement towards learner-centred instruction, particularly that which involves the use of information and communication technology (ICT) tools (Riihela & Maki, 2015, p.15). As a result, "Educators are being called upon to find ways to create classrooms that engage students by using digital media to enhance learning" (Lajoie, 2014, p.623).

The term 'multimedia learning' refers to the ability to learn from multiple representations, particularly verbal and visual representations, that present an instructional message (Mayer, 2014b). Its promise lies in the fact that "teachers can tap the power of visual and verbal forms of expression in the service of promoting student understanding" (Mayer, 2003, p.127). This type of learning involves computer-based lessons that contain animation and narration (Mayer, 2009) or, more simply, learning that occurs from words and pictures (Mayer, 2014c). The words usually take the form of explanatory text, either narrated or written, and pictures can be either dynamic (e.g. animations and videos) or static (e.g. photos and graphs) (Ayres, 2015).

2.3.5 Theories of multimedia learning

Multimedia learning theories largely focus on the cognitive processes involved in learning, such as selecting relevant information, "mentally organising the material into a coherent organisation, and integrating it with relevant prior knowledge activated from long-term memory" (Mayer, 2014a). Various theories have been presented as underpinning multimedia learning, including cognitive theory of multimedia learning (Mayer, 2009), integrated model of text and picture comprehension (Schnotz, 2014) and four-component instruction design model (Ayres, 2015). Another theory, however, cognitive load theory (CLT), is considered fundamental (Mayer, 2014a) and relevant to this study as noted in Section 2.3.1.

Both the cognitive load theory and the cognitive theory of multimedia learning also argue that poorly constructed materials increase working memory load, which results in ineffective learning. Learning materials that are well constructed, however, do use working memory, which is seen to be a main benefit from the perspective of these two theories. The adoption of a multi-modal approach using text and visual information is largely acknowledged as being of benefit (Ayres, 2015) and is referred to as the multimedia principle, outlined below.

2.3.6 The multimedia principle

The development of multimedia learning approaches has led to the establishment of the multimedia principle (Mayer, 2014c). The multimedia principle was first synthesised from research that focused predominantly on text combined with (static or animated) illustrations (Mayer, 1989; Mayer, Bove, Bryman, Mars & Tapangco, 1996; Mayer & Gallini, 1990). 'Multimedia learning' is a term that refers to learning that utilises at least two modalities (Butcher, 2014) – for example, words and pictures, compared with pictures alone. More recent references to the use of the principle, however, tend to relate more to learning that occurs when supported by numerous forms of visual and verbal content presented in combination (Butcher, 2014). It has been identified that "depending on the different modalities used and the form they take, the cognitive processes activated can vary and lead to different learning outcomes" (Ayres, 2015).

Examples of different multimedia elements include static illustrations, diagrams and images, as well as dynamic visual representations such as animations or videos. Adding static diagrams or illustrations to a verbal (text or audio) presentation frequently facilitates deeper understanding of the material to be learned (e.g. Butcher, 2006; Butcher, 2014; Cuevas, Fiore & Oser, 2002; Fiore, Cuevas & Oser, 2003; Moreno, Ozogul & Reisslein, 2011).

Advancements in the ability of computers to graphically display advanced dynamic forms of information have resulted in their use becoming increasingly common (Butcher, 2014). A recent meta-analysis by Hoffler and Leutner (2007), for example, identified the benefits of animations over static visuals. Other researchers (including Hegarty, Canham & Fabrikant, 2010; Paik & Schraw, 2013) found that visual and attentional cues facilitate more meaningful learning, provided the learner possesses the necessary domain knowledge required to process the cued content. This finding has specific relevance to this study because several multimedia 'supports' were used during the later stages of the data collection to further enhance the learning experience for the learner. These will be elaborated on later in this chapter.

2.3.7 Implications for instructional design

As noted by Butcher (2014, p.194), "research on the multimedia principle has strong implications for the design of effective learning materials". Also relevant are the guiding principles that aim to promote best instructional practice as identified by Reed (2010) after a study of the cognitive architectures underlying multimedia design was undertaken. These principles, summarised below, were also considered carefully during the design of the multimedia 'supports' used in this study.

Firstly, when engaging novice learners, visual representations should be broken down to their essential components, in the form of iconic representations (e.g. Butcher, 2006). Also, when presented to the learner, verbal information should be integrated with visual content, while animation should be considered if motion is a critical aspect of the to-be-learned content (Hoffler & Leutner, 2007). Visual clues may also be useful within static presentations if the desire is to facilitate meaningful processing of critical elements (see e.g. de Koning, Tabbers, Rikers & Paas, 2010). In this study, to support geographic inquiry using GIS, multimedia has been used to model technological and thinking skills.

While these considerations are noted, the most effective instructional designs provide careful attention to the nature of the materials to be learned and the characteristics of the learners targeted (Butcher, 2014). When instructional materials are implemented in digital environments, educators should consider the potential of interactive elements in engaging the learner. These can include the creation of integrated visual–verbal representations as shown by Bodemer, Ploetzner, Feuerlein, and Spada (2004), who used a mixture of printed text, dynamic and interactive visualisations on a computer and static illustrations with verbal, algebraic and graphic components on a computer.

Inappropriate multimedia content, however, can also cause stress resulting in an unchanged learning performance (Chen & Sun, 2012). Avoiding cognitive overload and stress is, therefore, a priority and this can be achieved with the use of appropriate learning materials and structures that guide students through the learning process and by considering students' preferences (Ocepek, Bosnic, Nancovska Serbec & Rugelj, 2013). Any instructional approach using multimedia learning must, therefore, consider the student's characteristics (Vogel-Walcutt, Gebrim, Bowers, Carper & Nicholson, 2011). In this study, careful consideration was given to the ability of the students participating in the interventions, with each intervention being undertaken with students of similar ability.

2.3.8 The use of screencasts as a hard scaffold

Screencast tutorials (or screencasts) are simply described as "a digital recording of computer screen activity, often with an audio commentary" (Raftery, 2011, p.665). They are a "video recording of movement on a computer screen, together with audio narration" (Loch & McLoughlin, 2011, p.817).

Instructional screencasts are increasingly used as part of online tutorials, particularly those offered by academic libraries (Ergood, Padron & Rebar, 2012). In a classroom context, screencasts can take a variety of forms. These include recorded lectures (Dey, Burn & Gerdes, 2009) or shorter mini-lectures, explanations of homework or exam solutions (Lee, Pradham & Dangarno, 2008).

The development of simple software tools for developing screencasts has enabled their introduction in a variety of contexts (Green, Pinder-Grover & Millunchick, 2012). This technology was originally used to demonstrate how to operate new software tools, but educators have begun to adopt screencasts to enhance student learning (Betty, 2009; Falconer, deGrazia, Medlin & Holmberg, 2009; Gardner & Jeon, 2010).

2.3.9 The benefits of using screencasts

While the research on multimedia learning is extensive, a growing number of researchers have investigated the role of screencasts as a proven means to facilitate learning (including, Betrancourt, 2005; Carr & Ly, 2009; Evans, 2011; Falconer et al., 2009; Harpp et al., 2004; Oud, 2009; Pinder-Grover, Green & Millunchick, 2011; Pinder-Grover, Green & Millunchick, 2008; Pinder-Grover, Millunchick, Bierwert & Shuller, 2009; Razik, Mammo, Gill & Lam, 2011; Rose, 2009; Thompson & Lee, 2012).

Screencasts assist with student learning when they are "learning a new application or when they need to self-regulate their learning process in their own pace" (Esgi & Kocadag, 2015, p.14). Their use can encourage students to study and learn in an active way by forcing them out of a 'passive' mode (Oud, 2009; Pinder-Grover et al., 2008). Screencasts may also be used as tools to demonstrate different ways of problem solving and to teach higher-order conceptual knowledge (Lloyd & Robertson, 2012). When screencasts are used in an online learning environment, users can "use their visual and auditory senses to learn complex concepts and difficult procedures" (Hartsell & Yuen, 2006, p.31). Students can view a screencast "at their own convenience and multiple times" and learners can see how to complete a task (Sugar, Brown & Luterbach, 2010, p.2).

2.3.10 Designing effective screencasts

According to Loch and McLoughlin (2011), there is very little by way of literature on the effectiveness of screencasts focusing on best practice of instructional design. Some, however, including Sugar et al. (2010), have produced the "anatomy of a screencast". The researchers conducted an inquiry to explore screencasts, analysing 37 screencasts, both their own selfproduced screencasts and those produced professionally. Their investigations identified common structural components (i.e. bumpers, screen movement and narration) and common instructional strategies (i.e. provide overview, describe procedure, present concept, focus attention and elaborate content).

A meta-analysis of literature surrounding 'podcasts' was also completed by Heilesen (2010), who noted it was not entirely clear whether engaging in podcasting was worthwhile, although their use may help improving study habits. Also, increasing student acceptance of podcasting may help improve the academic environment in which they are learning and thus result in "shorter time of study, higher rates of completion, and perhaps a higher academic level" (Heilsen, 2010, p.1066).

Several approaches can be utilised when designing and implementing screencasts (Murphy, 2015). Commonly, instructional theories are used to derive effective instruction guidelines (e.g. Mayer, 2009; Oud, 2009; Tewell, 2010). Principles in cognitive psychology can be drawn upon, for example, to minimise the burden on learners' short-term memory processing and reduce cognitive load. Useful strategies include:

- simplifying and focusing content around clear goals;
- presenting content so it is easy to understand the main points;
- ensuring the interface, technology, and practice activities can be completed easily, removing any words or graphics not absolutely needed; and
- directing attention to the most important points using visual and verbal cues (Oud, 2009, p.174).

Alternatively, guidelines are established by observing how tutorials are delivered in practice and then identifying key elements of what works most effectively (e.g. Bowles-Terry, Hensley & Hinchliffe, 2010; Oehrli, Piacentine, Peters & Nanamaker, 2011; Sugar et al., 2010).

Tempelman-Kluit (2006) investigated the effectiveness of HTML versus 'streaming media' as a teaching tool and produced a list of multimedia principles that support learning. The study considered a link between multimedia theory and instructional delivery in a library context by drawing upon cognitive load theory and cognitive theory of multimedia learning, as presented by Mayer (2009). The study examined the extent to which multimedia-learning theories differ from two versions of the same library instruction tutorial. The first version involved HTML, which is the more traditional format, while the second employed a learner-centred cognitive approach to multimedia learning. This second version was less traditional, in that it involved the streaming of audio and narration. The study found that the second form was more effective as a teaching tool.

Oud (2009) developed a checklist for effective screencast instruction and acknowledges cognitive load theory as being an important theoretical lens through which the guidelines are explored and developed. Oud's checklist is as follows:

1. Ask whether multimedia is needed;
2. Minimise cognitive load;
3. Include interactivity;
4. Promote critical thinking; and
5. Know your students.

Other studies also provide varying recommendations. Some researchers (including Bowles-Terry et al., 2010; Guo, Kim & Rubin, 2014; Mestre, 2012; Morris, 2012) suggest that screencasts should be kept short (no more than several minutes in length) or divided into longer segments. Others (e.g. Mestre, 2012; Raftery, 2011) recommend that learners should control the pace of the instruction. Further suggestions include ensuring that information relates directly to the instruction and is kept simple and avoiding non-essential elements (Bowles-Terry et al., 2010; Hess, 2013; Loch, Jordan, Lowe & Mestel, 2013). Finally, presenting in an informal style is considered important (Guo et al., 2014; Small, 2010).

Effective screencasts should focus on individual topics rather than repeating lecture content (Sutton-Brady, Scott, Taylor, Carabetta & Clark, 2009). This is a view supported by McCombs and Liu (2007, p.817), who suggest recording "complementary information rather than replicat[ing] existing information, and… add[ing] extra visual information to explain the content and to trigger 'new focus and attention'".

Should a screencast be deemed appropriate, it is essential that steps be taken to reduce the burden that multimedia places on working memory. By minimising the cognitive load in the three areas previously discussed (intrinsic, extraneous and germane), the learner can process information more effectively and learn better (Oud, 2009). Screencasts can place increased demands on a learner's short-term memory because large amounts of information (text, graphics, audio, motion) need to be processed simultaneously (Betrancourt, 2005). Wouters, Paas, and van Merrienboer (2008) support this view and argue the need for a cautious approach. Learners may find it hard to process information effectively from embedded multimedia, so its use as an instructional tool should only be considered if it is deemed helpful for learning (Oud, 2009).

Recommendations on minimising cognitive load include reducing content-related load or the content of the screencast by focusing on the key points that need to be shared in the screencast (e.g. Kosslyn, 2007). It is further suggested that the content, learning activities and assessments all be aligned with the goals of the activity (Carliner, 2002).

Minimising activity-related load can also be achieved by ensuring that all activities are within the capabilities of the students (Oud, 2009) and this can be achieved by presenting worked examples (Renkl, 2005) that are easy for the students to understand and are appropriate to their level of knowledge and understanding.

Reducing extraneous load is also imperative and involves simplifying and even removing any content that is not relevant to the activity. It is suggested that all irrelevant graphics, audio and text be removed, as they distract the learner (Mayer, 2006). Furthermore, the appearance of any graphics etc. needs to be consistent in style so that the effort to interpret them is reduced (Clark & Lyons, 2004).

In this study, multimedia scaffolds are used to show the learner how to complete a specific task using GIS. The GIS instruction is demonstrated in the video to guide the learner through the task they are required to complete.

2.4 Student ability and the impact on learning

The final area of focus for this research is the influence of ability levels on student learning. Finding the balance between common instruction for all students and targeted instruction to meet students' specific needs is a consistent challenge for all teachers. As noted by Collins (2007), this is challenging; student performance is affected by many variables, including the attitudes of the teacher, curriculum content, class size, teaching methods, ability range, resources and the degree of differentiation between ability groupings. The issue of student grouping is, therefore, considered in this research as it may or may not be a key determinant of student learning.

Traditionally, the role of the teacher was, as noted earlier in this chapter, to transmit information to the students (Bransford et al., 2000), using pedagogies that were largely aligned with behaviourist theories. Zohar et al. (2001) noted that, up until the 1970s, learning was linear and sequential, with complex understanding thought to occur only by the accumulation of basic prerequisite learning (Bloom, 1956; Gagne, 1974). Only those students who had mastered the lower levels could progress to higher cognitive stages; as a result, many low-ability students were left to dwell in lower-order thinking levels because they had not mastered the basic level of understanding (Zohar & Dori, 2003).

Similarly, there has been a view that thinking and reasoning skills are taught as an optional activity that may or may not take place. Instead, thinking must be applied to all learning and to all learners (Bransford et al., 2000) rather than the traditional view that only a select few enjoyed the privilege of an educational tradition that fostered their thinking (Zohar & Dori, 2003).

Many school practices and policies are built on the assumption that students learn best when the curriculum is well matched to students' learning abilities. Some (such as Zohar & Dori, 2003) note that low-achieving students are overly challenged, and thus frustrated, by teaching that includes activities focused on higher-order thinking. The belief is that when students understand what they are being taught, they are more likely to be actively involved in the learning process and less likely to disengage from classroom instruction (Hallinan et al., 2003).

Ideally, ability grouping should maximise student learning, as is the intention in this study; however, researchers (including Hallinan et al., 2003) note that there are limitations in the process of assigning students to ability groups and in the pedagogical techniques utilised at different ability group levels.

One problem is that allocation to ability groups relies on some combination of standardised test scores, grades or recommendation and, as a result, a student may be placed in an ability group that has a curriculum above or below the student's learning level. Another factor is that students assigned to higher-ability groups may attain higher test scores as the instruction that they receive may be of higher quality, more challenging and interesting, and students in these groups are immersed in a more academic climate, than those in lower-ability groups (Hallinan et al., 2003).

Grouping students into homogenous subsets by ability, for example, is a common approach as it allows the teacher to tailor instruction to a relatively restricted range of performance levels. While this practice appears to benefit students assigned to classes of high-performing students, it is detrimental to the achievement of students assigned to classes with low-achieving peers (Gamoran, 2011). The issue of whether student grouping is a key determinant of student learning is considered in this study.

While many studies in the literature focus on ability grouping in education (Catsambis, Mulkey & Crain, 2001; Felouzisa & Charmillota, 2013; Gamoran & Weinstein, 1998; Hallinan et al., 2003; Slavin, 1993; Vang, 2005; Watanabe, 2006), literature linking GIS-based learning to ability levels is scant.

One study uncovered examined whether a web-enhanced science inquiry curriculum supported by geospatial technologies promoted urban middle-school students' understanding of energy concepts (Kulo & Bodzin, 2013). In this research, student classes were organised according to their mathematics ability level, which was determined by a state-wide standardised test. The study, of 108 eighth-grade students involved completing pre- and post-test knowledge assessments, classroom observations and reflective meetings with the teacher. The results of the study showed a significant increase in the students' understanding of energy knowledge and that all classes recorded an effect size. Interestingly, the middle- and low-ability classes had larger effect sizes than the high-ability class.

By comparison, in this study participants are also grouped according to ability (middle and high ability) and improved learning outcomes are determined during the data collection process. In contrast, however, the improvement scores are used to identify the extent to which student thinking skills are enhanced as a result of different pedagogical approaches.

This literature review has sought to provide relevant information that is pertinent to this research. The overarching emphasis is to determine the effectiveness of different methods of instruction in developing student thinking skills and, as such, the chapter provides a cogent summary of learning theories that underpin each pedagogical approach. In particular it focuses upon relevant literature relating to student-centred and direct instruction instructional frameworks. Following on from this, the literature review examines the geographic inquiry method and the link of this form of instruction with student thinking skills. Furthermore, it explores the link between the thinking skills and Bloom's revised taxonomy, a central underpinning framework used to develop the instructional materials in this research. The literature review then explores how scaffolding can be used to support learning outcomes and the development of thinking skills. In particular, it examines different forms of scaffolding with reference to teacher modelling and multimedia, both of which have been identified in the literature as effective in supporting student outcomes. Finally, the cognitive implications of scaffolds are examined, as this is a key consideration throughout this study, particularly in relation to the design of the instructional materials.

Chapter 3: Methodology

This research seeks to understand, document and interpret GIS-based pedagogical approaches that are most effective in improving student thinking and learning outcomes. In doing so, it seeks to change and improve educational practice in this area and contribute to the body of research around GIS-based instructional frameworks. For this to occur, the methodology used must link 'theory with practice' and enable the results to be validated. This can be achieved if the interventions are systematically adjusted throughout the experiment with the results validated by examining the consequences of their use. The study is, therefore, undertaken within a classroom setting in which it was possible for the results to be collected, interpreted and analysed using an approach that other researchers can replicate.

3.1 Design-based research (DBR) methodology

With this consideration, a design-based approach was adopted for this study. Design-based research is commonly used by educators "to increase the impact, transfer and translation of education research into improved practice" (Anderson & Shattuck, 2012, p.16). The iterative cycle of data collection and analysis, which is characteristic of design-based research, allows the researcher to refine the principles of specific interventions using information interpreted from the data collected (Mantei, 2008). Being able to engineer the environment provides a measure of control when compared with purely naturalistic investigation, allowing effects to be detected (Cobb & Confrey, 2004).

In their analysis of a decade of investigating design-based approaches, Anderson and Shattuck (2012) suggest that quality design-based research is defined by several different features. This study has been designed to incorporate these features.

Firstly, the study is situated in a real educational context to provide a sense of validity to the research. In the current study, the investigation was undertaken using student participants and sought to assess the use and application of GIS in a secondary geography context.

Secondly, the study focuses on the design and testing of a series of interventions. This process was undertaken collaboratively with both researchers and teachers to ensure that the study was relevant to the local context and is, therefore, transferrable to other classroom settings.

Thirdly, it is an approach in which a wide variety of measures can be incorporated and, as a result, it "is perfectly logical for researchers to select and use differing methods, selecting them as they see the need, applying their findings to a reality that is both plural and unknown" (Maxcy, 2003, p.59). This study uses both qualitative and quantitative data collection instruments in a mixed methods approach.

3.2 Mixed methods research

While design-based research provides the overarching methodological approach, mixed method techniques were adopted within the specific iterations to evaluate the effect of different interventions. In the broader social sciences, mixed methods research has become increasingly popular and is now considered a legitimate research design in its own right and a distinct method of inquiry used by various researchers (see Creswell & Plano Clark, 2007, 2011; Long, 2017; Teddlie & Tashakkori, 2009b). Over time, it has developed into a popular approach in sociology, psychology, health sciences and education (Molina Azorin & Cameron, 2010).

A key principle of mixed methods research is that both qualitative and quantitative components of the study are 'mixed' (Maudsley, 2011; Simons & Lathlean, 2010) or combined into a single study. This approach produces a fuller account of the research problem (Glogowska, 2011; Zhang & Creswell, 2013) and is, therefore, equally valued as quantitative or qualitative studies alone (Creswell, 2015). According to Pearce (2015), mixed method research enables a holistic perspective on research to be applied with several stances or viewpoints adopted. The approach offers the potential to explore underlying research paradigms and worldviews (Gelo, Braakmann & Benetka, 2008) and for quantitative effects on outcomes to be measured along with the qualitative perspectives of the participants (Johnson & Onwuegbuzie, 2004; Richey & Klein, 2008).

Several authors (including Andrew & Halcomb, 2009; Hanson, Creswell, Plano Clark, Petska & Creswell, 2005; Scammon et al., 2013; Wisdom, Cavaleri, Onwuegbuzie & Green, 2012) argue that, by combining qualitative and quantitative research, mixed methods research can capitalise on the strengths of both approaches while at the same time limiting their weakness, resulting in an integrated and more comprehensive understanding of the research topic or question. The mixing of both quantitative and qualitative approaches is likely to result in "complementary strengths and non-overlapping weaknesses" (Johnson & Onwuegbuzie, 2004, p.18).

Another strength is that the collection of both quantitative and qualitative data simultaneously during a single data collection phase means that more meaningful findings can be obtained through in-depth analysis of both data sources (see Teddlie & Tashakkori, 2003; 2009a). In addition, the researcher can answer a broader and more complete range of research questions because the researcher is not confined to a single method or approach. Words, pictures, and narrative discussions can be used to add meaning to quantitative values; similarly, numbers can be used to add value to words and qualitative information, including pictures.

There are criticisms of the mixed methods approach (see e.g. Bryman, 2012; Creswell, 2009, p.215; Zou, Sunindijo & Dainty, 2014), including that the approach can be time consuming and expensive, and that the researcher needs to have experience in multiple methods and knowledge about how to mix them. It can also be difficult for a single researcher to undertake both quantitative and qualitative research at the same time.

In the case of this research, quantitative and qualitative data analysis was performed concurrently. The quantitative results were used to determine the impact of the effects of the interventions, while the qualitative data helped inform the redesign of the interventions at different stages of the study. The combination of both quantitative and qualitative research produced a more complete understanding of the phenomena under investigation in a way that could inform theory and practice. Table 7 summarises the quantitative and qualitative techniques that were adopted within this study.

Table 7. Methods and Techniques used in the research study

Methods used	Techniques
Quantitative Methods	- Standardised pre-test of student knowledge containing short answer questions and a seven-point Likert scale questionnaire - Standardised post-test of student knowledge containing short answer questions, a seven-point Likert scale questionnaire and qualitative questions
Qualitative Methods	- Observations of the students (audio-visual equipment used to record the interventions) - Interviews with the student's post-treatment - Interviews with the teacher post-treatment

3.2.1 Concurrent nested design within each iteration

Quantitative and qualitative data was collected concurrently in this study using a concurrent nested design – a situation in which both forms of data are analysed together during the data analysis stage. This approach is referred to as a 'nested' design, which implies that one research approach is dominant, with the approach with less weight (in this case, qualitative) nested within the other (in this case, quantitative). The purpose of adopting this approach is to consider a broader perspective on the research question than could be gained from using only quantitative data.

The design adopts a two-stage approach for the nested data, with the quantitative and qualitative data collection occurring sequentially and with limited time-lag. The quantitative data was collected in both a pre- and post-test phases while qualitative data was collected in the post-test phase as well as a follow-up focus group. The typology of the research design is shown in Figure 5.

In this research, the quantitative results play a primary role, determining the extent of the effects, while the qualitative results play a supportive, but important, role in determining whether there was an explanation for the effects. The results will then be used to consider how the GIS-based interventions might be improved in future iterations, studies and classroom practices.

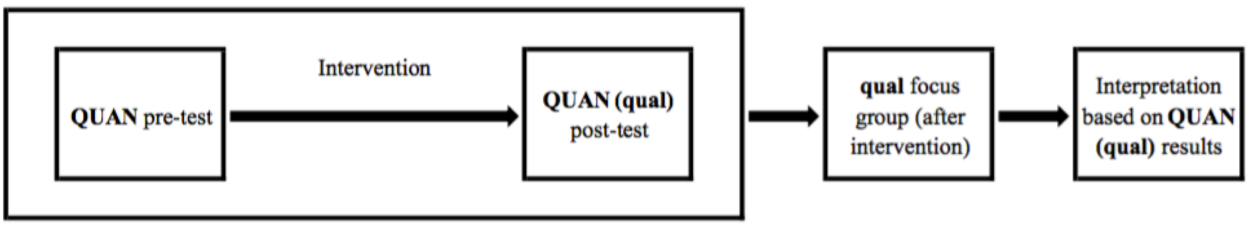


Figure 5. Concurrent Nested Mixed Design adopted for each iteration in this research study
Source: (Creswell, 2009)

There are some weaknesses of the concurrent nested mixed design, as the collected data needs to be transformed in such a way that it can be integrated into the analysis. This transformation can be a challenge, as there is an unequal weight between the quantitative and qualitative data that may result in the results being interpreted unequally in the study (Creswell, 2009, p.215). Therefore, careful consideration of how the qualitative and quantitative data is mixed in this design is needed (see Bryman, 2012; Zou et al., 2014); consequently, the analysis of data in this study placed more emphasis on the quantitative results as a source of objective findings but used the qualitative results to interpret those findings.

3.3 Research context

This research is set within the context of secondary geography education in New South Wales, Australia. At the time the research was undertaken, geography was a mandatory area of study in Years 7–10 (Stages 4–5). The Stage 4–5 syllabus was prescriptive in nature and encouraged the use of GIS-based activities in the teaching of geography. The syllabus's prelims stated: "when using geographical tools teachers could also use geographical information systems (GIS) as appropriate to support student learning in geography" (Harwell, 2011). The content of the syllabus document specifies key topics and there is flexibility within each to include a range of ICT, including GIS.

3.4 Participants

The target population for the study consisted of students commencing Year 9 (9th Grade) at an independent boy's school in Sydney. Data collection took place in 2011 and 2012, at the time when the researcher was employed at the school. The school is an independent Christian day and boarding school comprising approximately 1500 students from kindergarten to Year 12 (the final year of schooling in New South Wales) and has approximately 430 boarders. Students were drawn from Year 9 classes streamed based on their previous year's results in social science (geography and history) and English.

The students at the school comprised a mix of day students (approximately 65%), weekly boarders (approximately 19%) and full boarders (approximately 16%) drawn from both within and outside the Sydney metropolitan area. The participating students' ages ranged from 13 years to 14 years. The teacher who taught all classes was a trained geography teacher and delivered the instruction required for each intervention. At the time of the study, the teacher had eight years' experience and was thirty-two years of age. To access this population, permission was granted by the Headmaster and executive of the school with university ethics approval granted (Ref No: 5201001530).

3.5 Procedures

The design-based research approach for the study was characterised by four phases, as shown in Figure 6. Figure 5, which outlines the concurrent nested design, relates to the iterations that took place during Phase 3.

3.5.1 – Phase 1

In this phase, a detailed review of the literature (as outlined in Chapter 2) was undertaken and the problem to be investigated was identified. This problem is presented as the research question and additional sub-questions, along with the literature review.

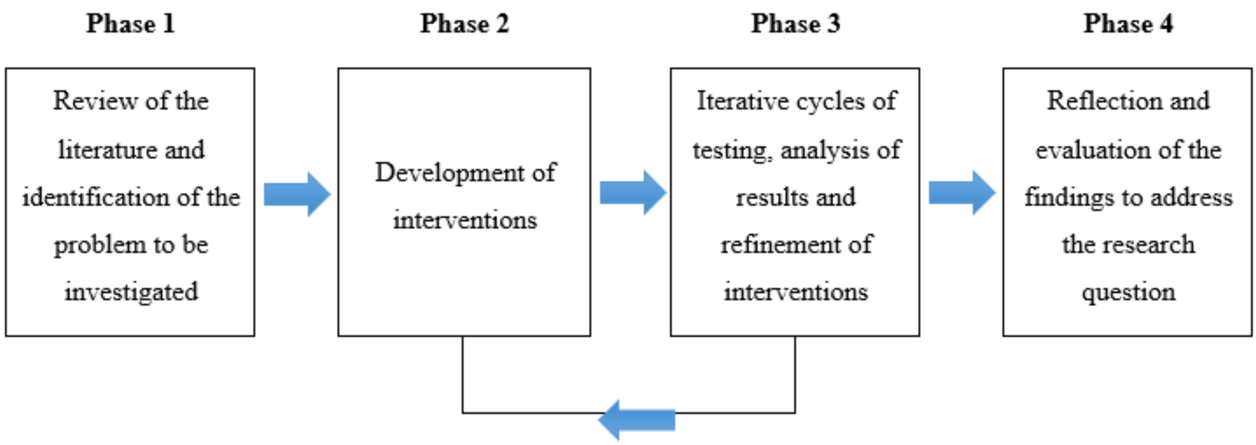


Figure 6. The phases of design-based research in this study

Source: Adapted from Amiel and Reeves (2008) by the researcher

3.5.2 – Phase 2

During this phase, three interventions were designed and included both quantitative and qualitative methods using the concurrent nested mixed design. Two groups were included in each intervention, with the students allocated to these groups using a random numbers table.

Two GIS-based lessons were developed for use within each intervention using two different teaching pedagogies, direct instruction (DI) and guided discovery (GD). These pedagogies were chosen as they contain elements of behaviourist and constructivist learning theories and this enables two GIS-based teaching pedagogies to be compared in this study. Each lesson was carefully designed, with the teaching materials aligned with each instructional approach using Bloom's revised taxonomy (Creswell, 2009, p.210). Two different topics were identified for use in the study, Development and Energy. Direct instruction and guided discovery versions of each unit were developed. Each of the instructional booklets used by the students is presented in Appendix A.

While the DI lesson was designed to enable the students to be directed by the teacher with specific instructions, a scripted presentation was created to ensure that all steps in the teaching sequence were followed and that all questions and instructions were clear. Specific instructions were given to the teacher, who was directed to deliver the lesson by holding the attention of the students in a traditional or didactic fashion. The teacher was also asked to give students the opportunity to respond to the teacher's questions or prompts during the lesson so that they could provide immediate feedback and correction.

The GD lesson was created in such a way that students could work in groups and the teacher was advised to provide clear objectives to each group, after initial input and explanation was provided. The teacher was further instructed to provide a series of questions to enable the learner to follow a guided set of investigations and to help them to engage in active enquiry. Understanding was also reinforced by the teacher through the application of problem oriented or task-based work. Inferences and tentative conclusions were drawn and shared across the groups.

In each intervention, the procedure followed a design experiment in the form of a 2 x 2 counterbalanced design. A 2 x 2 counterbalanced design is an experimental approach whereby the same participants take part in each condition of the independent variable – in this case, the pedagogy. This approach means that the conditions of the treatment are applied to the same group of participants. Shown in Table 8, this is a simple approach in which participants are allocated to the different conditions or independent variable groups.

Table 8. The 2 x 2 Counterbalanced design

Random Assignment to groups of approximate equal ability	
Group I	**Group II**
Pre_A X_A $Post_A$	Pre_A Y_A $Post_A$
Pre_B Y_B $Post_B$	Pre_B X_B $Post_B$

X = Pedagogy 1 (Direct Instruction)	A = Topic A (Development)	Pre = Pre-Test
Y = Pedagogy 2 (Guided Discovery)	B = Topic B (Energy)	Post = Post-Test

Counterbalanced designs have been used frequently in educational technology research and there are numerous references to their application in the literature (Dolan, Hall, Banerjee, Chun & Strangman, 2005; Edwards & Rule, 2013; Fitzgerald & Koury, 1996; Maccini, Gagnon & Hughes, 2002; Spooner, Jordan, Algozzine & Spooner, 1999; Stowell, 2010). The advantage of this approach is that time is saved because fewer people are required, as they all take part in all conditions.

The disadvantage of applying two treatments to the same group is that there may be order effects, which refers to the potential for the 'order' of the conditions to influence the behaviour of the participant. If an order effect is evident, it may be such that the performance in the second condition is better because they are aware of what to do, or worse because they are fatigued.

To counteract this, researchers use counterbalanced designs to detect whether the order of treatment or other factors influenced the results of the experiment. An important characteristic of this design is that the participants were randomly assigned to groups, each of which was exposed to varying sequences of treatment conditions (within their ability level) to balance out routine order effects. The first group completed their first lesson (Topic A) using Pedagogy 1 (direct instruction), while the other group completed their first lesson (Topic A) using Pedagogy 2 (guided discovery). Then, after this lesson was finished, the groups switched topics and pedagogies. Following this procedure meant it was possible to eliminate sequencing of pedagogy or topic difficulty as the cause for any difference between improvements based on pedagogy. The design enabled examination of whether DI is more effective as a GIS-based pedagogy than GD, or vice versa.

After the instructional materials were prepared, a short *pilot study* was completed to trial the proposed procedure on a group of 'test' participants. This group comprised 23 students not involved in the formal study, which enabled the teacher to check the procedures and research instruments. Several changes were made, particularly in relation to the types of questions used on the instruction sheet to be followed by participants in the computer-based part of the study. The pilot study also provided an opportunity to gain feedback on how clear the instructions were and how well the GIS projects worked.

3.5.3 – Phase 3

During this phase, iterative cycles of testing, analysis of results and refinement of interventions occurred. Prior to each intervention the researcher met with the teacher administering the test, to discuss any concerns or questions that they might have before the tests began and to ensure the teacher was fully prepared on the day of the intervention. The test was delivered in an IT suite at the school and each computer had ESRI's GIS program ArcMap 9.2 installed. The application deployed on the school IT network and GIS data used by the program were stored on the school's network drives.

For each iteration, the rooms were set up with tables around the outside and an island bench on which other PCs were placed. Two digital video cameras were set up at opposite sides of the room to record the interventions for the duration of the task. There was a digital projector and screen at the front of the classroom. The room was large enough to accommodate all students in the class comfortably and the room was well ventilated with air conditioning.

Before the students entered the room, the researcher placed the pre-tests face down on the tables in front of the computers. After a class roll was taken to check who was absent, students were instructed to spread around the room but ensure that there was a PC in front of them. They were also instructed not to turn over the papers until instructed to do so. Students were then instructed to turn the papers over and put their names at the top of the pre-test. They were then asked to wait for further instructions.

The tests were administered over two 1-hour lessons on Day 1 and two 1-hour lessons on Day 2, at the same time on each day. Adhering to the counterbalanced design presented in Table 8, Group I completed the 'Development' task, which adopted a direct instruction approach. They were followed two hours later by Group II, who completed the 'Energy' task, also administered using the direct instruction approach.

The following day, the starting order and pedagogy for each group was changed, with Group II completing the 'Development' task administered using a guided discovery approach. They were followed two hours later by Group I, who completed the 'Energy' topic delivered using the guided discovery approach.

In the intervention, each student completed a standardised pre-test, instruction booklet and post-test comprising questions developed to assess student knowledge and thinking; these are presented in the appendices. The questions were aligned to the levels set out by Anderson and Krathwohl (2001) and students were required to complete all sections. The pre-test and post-test comprised a variety of questions designed to collect both quantitative and qualitative data. Likert scale items relating to general aspects about technology, GIS and instruction were incorporated in the pre- and post-test. The post-test also contained several open-ended questions that provided students with the opportunity to share some qualitative feedback about the task. In particular, students were able to note what they enjoyed and didn't enjoy about the lesson and how they felt the lesson could have been improved. The qualitative questions in the pre-test were not identical to those in the post-test but were specifically designed to assess the same skills at the same cognitive domain level. The documents were distributed at the start of the lesson and collected once the lesson was completed at the end of the two hours.

The pre-test did not require students to use the GIS but it was designed to ascertain prior knowledge and understanding about the respective topics. Students then completed the instruction booklet using their own knowledge and that acquired from using the GIS program. The post-test was then completed and used to assess the knowledge learnt from the lesson compared with the information collected in the pre-test. The pre-tests and post-tests are presented in Appendix B. A standardised mark scheme was prepared to assess the learning in the pre-test and the post-test (see Appendix C). These were marked by the researcher immediately after the tests were collected.

The quantitative and qualitative data after collection in the instruments was processed using different software programs. The Likert scale data, and the results of the pre- and post-tests, were collated using Excel and statistical analysis was conducted using the Excel Analysis ToolPak, an add-in package that provides additional data analysis tools for statistical analysis.

The qualitative data, collected as open-ended responses in the post-test as well as the focus group responses, was transcribed and organised using computer-assisted qualitative data analysis software. The software used to perform this analysis was NVivo, a qualitative data analysis computer program produced by QSR International. The software allows rich text-based and multimedia information to be analysed at a deep level by organising unstructured data in a structured way. In this research, NVivo was used to organise, sort and arrange the student responses in a way that enabled qualitative coding to be performed and relationships to be explored between each data set. From this, key themes or nodes were identified and reported on. A full explanation of data analysis techniques is provided in Section 3.9.

The same instructional materials were used in each intervention (1, 2 and 3), although some minor changes to the formatting and grammatical changes were made after the first intervention. Within each intervention there were four iterations, which were completed in a two-hour time slot for each iteration, with the entire intervention occurring over a two-day period. During this time both the quantitative and qualitative data was collected using different instruments and techniques.

The first intervention occurred on 15 and 16 June 2011 using 33 male participants (n=33) of middle ability; these students were drawn from the 3rd and 4th class in the year group, which comprised six classes. Students were randomly assigned to groups (Group I and II) to balance the participants and ensure as much as possible that there were two groups of approximately equal size and ability. Group I contained 17 students and Group II contained 16 students.

The day after the interventions were completed, a focus group discussion was conducted with a group of 12 students who volunteered to be interviewed during a lunch break. This discussion was held in a classroom in the Geography Department and took approximately 30 minutes. Set questions were prepared by the researcher who led the discussion. The same questions were used for all three interventions. The questions (presented in Appendix D) were designed to provide the students with the opportunity to share further thoughts about the intervention and these were recorded on a digital video camera set up behind the researcher. The dialogue recorded on the video was transcribed in NVivo and coded using common themes aligned to those identified in the open-ended questions from the post-tests. The teacher who administered the test was also interviewed and his observations were noted.

The second intervention took place on 16 and 19 September 2011 and the same procedures were followed. This intervention was conducted with 40 male participants (n=40) of high ability drawn from the 1st and 2nd English classes, thereby representing the ablest two classes in Year 9 (9th Grade). This intervention was designed to investigate whether the same effects as Intervention 1 occurred with students of high ability. The students were also randomly assigned to one of two equal sized groups (Group I and II) to ensure the groups were of approximate equal ability. Group I contained 23 students and Group II contained 17 students. There was a difference of six students who were absent on the second day of the intervention and were therefore unable to complete the full treatment. Following the intervention, a focus group discussion was conducted the next day with a group of 13 students who volunteered to be interviewed at lunch time during the school day.

The third and final intervention occurred on 7 and 8 June 2012 the following year, again using the same procedures. This intervention included 34 male participants (n=34) drawn from a new set of English students who had entered Year 9 (9th Grade) that year. The students were drawn from the 3rd and 4th English class in the year group (from a total of six classes, so of middle ability) and randomly assigned to one of two almost equal groups in terms of size. The purpose of this was again to ensure the groups were of approximate equal ability. Group I contained 15 students and Group II contained 19 students. There was a difference in the numbers because a small number of students were not in attendance on either the first or second day or the testing. As with interventions 1 and 2, a focus group was conducted the next day during the school lunch break with 13 participants.

The data analysis techniques are described in Section 3.8 below.

3.5.4 – Phase 4

In this phase, summative reflection and evaluation of the results occurred; this process enabled the research question and sub-questions to be addressed. After the data was analysed in Phase 3 using

Excel and NVivo, key themes were drawn out and collated in such a way as to allow the information to be synthesised and reported. This information is presented in the discussion and conclusion.

3.6 Variables

The mixed methods approach adopted in this study uses quantitative and qualitative methods to evaluate dependent variables based on changes to the independent variables as shown in Table 9.

Table 9. Dependent and Independent Variables to be evaluated in the study.

Variable	Attribute of the variable to be evaluated	Description
Dependent Variable	Achievement	The amount of improvement in learning that has occurred from pre-test to post-test. Students completed set questions that were assessed using standardised marking criteria and were consistent across all three interventions.
	Thinking Skills (Higher Order and Lower Order)	In each intervention, the worksheets completed by the students were designed using the revised taxonomy provided by Anderson and Krathwol (2001). There were six parts in each worksheet, with parts 1–3 containing lower-order thinking questions and parts 4–6 containing higher-order thinking questions. Students' thinking skills were assessed by evaluating student performance in each part and collectively as either lower-order (parts 1–3) or higher-order (parts 4–6). The results were then collated and analysed.
Independent Variable	Pedagogy	Two different instructional techniques or pedagogies (guided discovery and direct instruction) were evaluated in the interventions as it was presumed that each would cause changes in the dependent variable.
	Hard scaffolds – multimedia video screencast	During Intervention 3, multimedia video scaffolds were introduced to the direct instruction approach at the higher-order cognitive levels, in response to the results obtained in interventions 1 and 2. These were designed to provide further opportunities for the students to engage with the GIS-based tasks that engaged higher-order thinking skills.
	Hard scaffolds – explicit instruction from teacher and guided demonstration	During Intervention 3, additional guided instructions (scaffolds) were delivered by the teacher in the guided discovery approach at the higher-order cognitive levels, in response to the results obtained in interventions 1 and 2. These were designed to provide further opportunities for the students to engage with the GIS-based tasks that engaged higher-order thinking skills.

3.7 The research instruments

As noted in Section 3.6.2, the research instruments developed in Phase 2 and implemented in Phase 3 of this study, were developed using Anderson and Krathwohl's (2001) taxonomy of educational objectives. In this study, lower-level tasks were identified as occurring at the remembering, understanding and application levels of the taxonomy, while higher-level tasks required more complex analysis, evaluation or creation skills. Each of the lessons incorporated both tasks and questions that increased in their complexity, thereby engaging students' thinking along a continuum from lower to higher order.

At each task level, appropriate questions were chosen to develop these thinking levels. Lower-order questions were used to evaluate students' preparation and comprehension, determine strengths and weaknesses, and to review and/or determine base-level knowledge. Questions at higher levels encouraged students to think more deeply and critically and to problem-solve, encouraged discussions and stimulated students to seek information on their own.

An extended period was dedicated to the development of the instrument, with both supervisors involved in several cycles of refinement. An external expert from outside the supervisory team was consulted to validate the alignment with the instructional and assessment materials with Anderson and Krathwohl's (2001) cognitive process levels. Sample questions for the development topics are shown below in Table 10; these are presented in in their entirety in Appendix A.

Table 10. Cognitive domains from Bloom's revised taxonomy (Anderson and Krathwol, 2001) and related questions from the instructional materials used in each iteration (Development topic).

Cognitive Level	Features of Cognitive Level	Sample Questions
Remembering	Recall or recognition of specific information	What do you understand the word 'development' to mean?
Understanding	Understanding of given information	What could you learn from a map that showed patterns of death rates around the world?
Applying	Using strategies, concepts, principles and theories in new situations	Which areas of the world appear to have a high and low literacy rates? What is this likely to indicate?
Analysing	Breaking information down into its component elements	Use the GIS to complete the following tasks: • Using the 2006 Human Development Index (HDI) data, describe the pattern of development around the world. • Compare the changes in development around the world between 1975 and 2006. • Can you suggest reasons for this?

Cognitive Level	Features of Cognitive Level	Sample Questions
Evaluating	Judging the value of ideas, materials and methods by developing and applying standards and criteria	Using the data and GIS analysis techniques used thus far, consider the following hypothetical situation: A wealthy western company has offered to provide funding to help improve standards of living for people living in an African village. The village is typical of those in many African countries with limited access to the most basic needs, including food, clean water and medicine. The company would like its funding to go towards: • improvement of mobile phone networks • funding for the building of schools • medical supplies and drugs for immunisation • purchase of computers for schools • development of tourist and safari parks • investment in renewable technologies • improvement of roads and cycle paths • education programmes about contraception. You are an expert at the United Nations specialising in development issues. It is your job to look carefully at the company's funding proposal and evaluate the strengths and weaknesses of the plan.
Creating	Putting together ideas or elements to develop or engage in creative thinking	Using the data and GIS analysis techniques used thus far, consider the following hypothetical situation: As an expert in development issues employed at the United Nations, you are regularly called upon to provide advice about how to measure living standards around the world. Recently, there has been significant criticism of the 'HUMAN DEVELOPMENT INDEX', with many people suggesting that it is no longer the best means of measuring development. As a result, you have been asked by the Secretary-General of the United Nations to develop a different index to measure the quality of life of people living around the world. You need to: • create a new name for the index • outline the criteria that the index is based upon • explain why it is a better measure of human development than the HDI.

3.7.1 GIS software tools used in the instrumentation

The ArcGIS software used by the students to complete each intervention contains a wide range of tools and functions for performing analysis on spatial data. Two tools that supported each student's thinking at the Applying and Analysing levels were utilised. They were the *Swipe Layer* tool and the *Flicker* tool.

The *Swipe Layer* tool is used to interactively reveal the layer beneath the top layer that is being swiped, allowing the user to more easily see what is underneath a layer without having to turn the layer off in the table of contents. The *Swipe Layer* tool is activated using the 'Effects' toolbar in ArcGIS desktop software and this is shown in Figure 7 below.

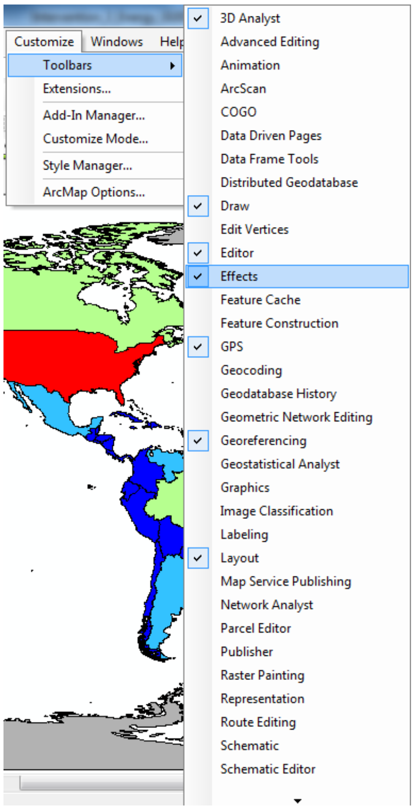


Figure 7. Activating the 'Effects' function in ArcGIS Desktop

Once this is activated, it is possible to select specific tools such as the *Swipe Layer* or Flicker tool.

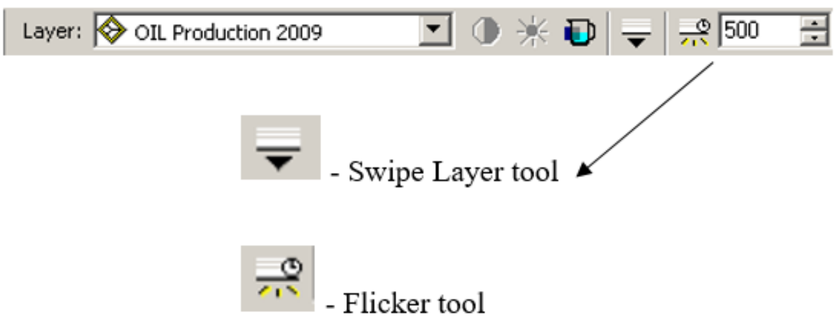


Figure 8. Swipe and flicker function in ArcGIS

Two data layers are then selected from the Table of Contents, as shown below in Figure 9.

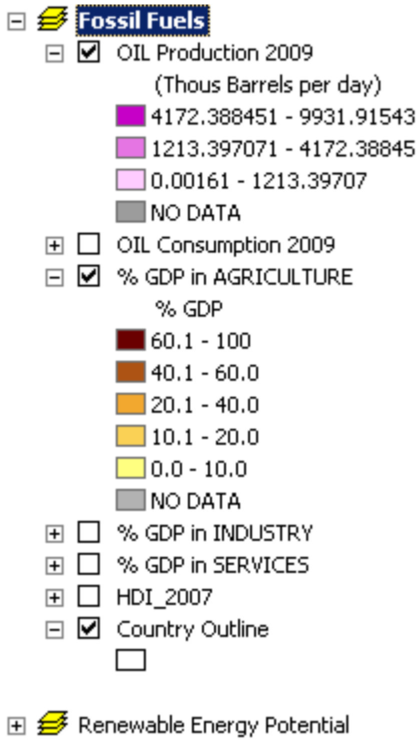


Figure 9. Table of Contents in ArcGIS Desktop

This process allows the user to then interact with the data interactively to compare different data layers. Figure 10 shows how oil production appears when mapped in a GIS.

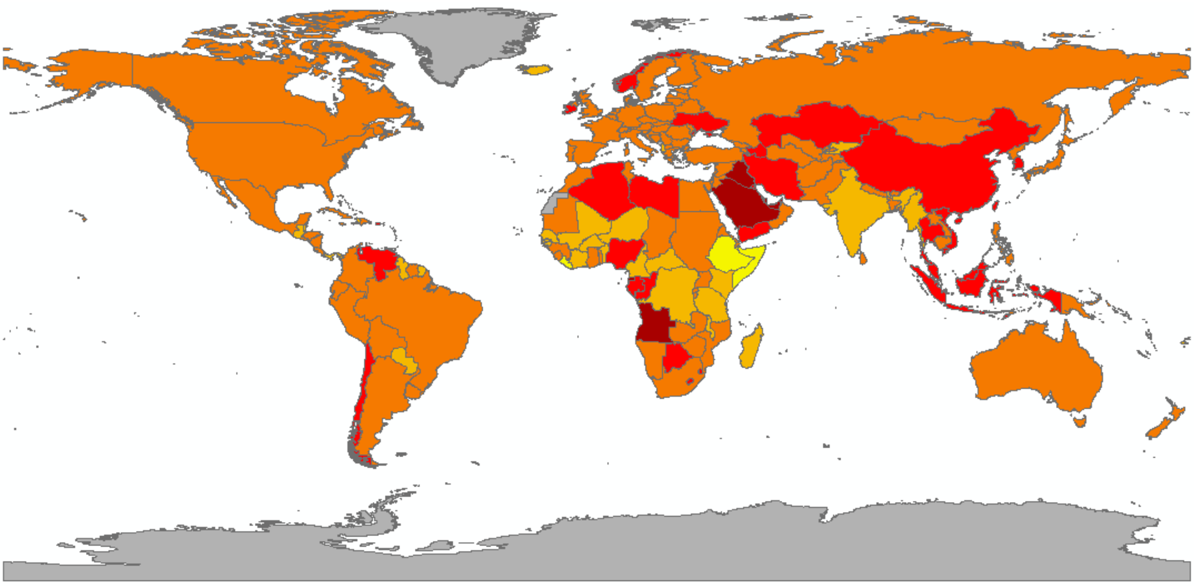


Figure 10. GIS map showing how oil production appears when mapped in a GIS

3.7.2 Instrumentation changes – Intervention 2

After reviewing the qualitative data collected in the post-tests and the focus group interviews, some minor modifications were made to the research instrument to ensure the task instructions were more succinct in their presentation. This action was taken in response to feedback from students that the wording and phrasing of some sentences in the task booklet was not as clear as it could have been. Students were required to respond to several questions in the same way and it was decided to slightly reduce the number of these repetitive actions. These were only minor modifications and they were not deemed to have a material impact on any of the research results.

3.7.3 Instructional changes – Intervention 3

As discussed in Chapter 2.3 of the Literature Review, scaffolding is a pedagogical process used to support learners to perform tasks they cannot do themselves (see de Jong & Lazonder, 2014; Hmelo-Silver et al., 2007; Lajoie, 2014; Shin, Brush & Glazewski, 2017). Brush and Saye (2002) identified two forms of scaffolding, hard and soft, with both appearing in different forms depending on the support required in the learning activity. Hard scaffolds are static supports planned in advance of an activity when it is anticipated that potential difficulties will be faced by the learner during the task. An example of this includes the use of multimedia video screencasts embedded within a learning environment to provide students with support while engaging with a specific problem (see Dunn, McDonald & Loch, 2015; Krajcik et al., 1998; Simons & Klein, 2007). In contrast, soft scaffolds are "dynamic, situation-specific supports provided by a teacher to help with the learning process" (Shin et al., 2017, p.1). This form of scaffolding may involve a teacher providing prompts or clarification during a learning task (Kim & Hannafin, 2011); this may be unplanned and offered as and when the teacher deems it appropriate to do so.

An enhancement was made to Intervention 3 with the addition of more explicit instruction, in the form of scaffolding, provided to help students achieve the higher-order cognitive domain levels. This action was undertaken in response to the feedback provided by students in the earlier interventions, in which they specifically requested that more explicit instructions be provided to enable them to effectively complete the task using the GIS. The central rationale for giving additional support to students to complete the questions at the higher-order thinking levels – analyse, evaluate and create – was that the results from Intervention 1 showed that middle-ability students were unable to complete the higher-order thinking tasks adequately, while the high-ability students could do so in Intervention 2 (see Results chapter). Consideration was then given to the factors that might be contributing to the middle-ability student's inability to engage effectively with the higher-order thinking tasks in Intervention 1. As discussed in the literature review, several authors (including Betrancourt, 2005; Oud, 2009; Wouters et al., 2008) have noted the importance of minimising the cognitive load on the learner so that they can process information more effectively and achieve better outcomes. In response to this, the decision was made to provide additional scaffolding to support the learner from overloading the limited cognitive capacity of the learner completing the GIS-based activity.

As a result, two forms of hard scaffolding were added to the learning activity. These were:

- a multimedia screencast embedded in the direct instruction approach; and
- explicit guided instruction by the teacher in the guided discovery approach.

The decision to select these two forms of hard scaffolding came after careful consideration of the nature of the pedagogy within which they would be delivered. For the DI approach, the multimedia screencast was deemed more appropriate as the instructions were delivered more explicitly in the form of a video and, as such, were aligned to the principles of this pedagogy. For the GD approach, a hard scaffold approach was also prepared; however, it was delivered by the teacher using verbal instructions and in an open forum in which students could respond interactively. This approach was deemed to be better aligned with the principles relating to the GD pedagogical approach.

The additional scaffolding was prepared only for the higher-order cognitive sections of the GIS-based activity, as the results from interventions 1 and 2 (which are reported in Chapter 4) indicated that the student's lower-order thinking skills were developed to some extent due to the GIS-based instructions in the learning task. The additional scaffolding was prepared either in the form of a multimedia screencast (direct instruction) or explicit guided instruction (guided discovery). The tasks to which the additional scaffolding applied related to the worksheet at the three higher-order cognitive levels – Analyse, Evaluate and Create. Once the tasks were identified, the multimedia screencast and the explicit instructions were prepared.

The video was created by the researcher using Microsoft Expression Encoder 4 software and its purpose was then explained to the teacher, along with guidelines about how it should be used during the lesson. The teacher was instructed to show the video at the start of each of the higher-order cognitive sections. The advantage of using the video was that the instructions expected of the students could be clearly shown with an explanation given about how to use specific GIS tools to complete the Analyse, Evaluate and Create cognitive tasks.

The same instructions were prepared for the teacher delivering the guided discovery approach. Instead of using a video to show the instructions, the teacher demonstrated the tasks using an

Interactive Whiteboard (IWB). Again, the additional scaffolding was shown at the start of each of the higher-order cognitive sections of the GIS-based activity.

3.8 Data analysis

To evaluate performance between the two groups in each Phase 3, pre- and post-tests were used. These tests comprised six parts, with each section relating to each of the six categories of Anderson and Krathwohl's (2001) taxonomy, and assessment rubrics were used to evaluate the responses. The design of the pre- and post-tests was critical to the success of this experiment. These measures were used to assess the extent to which the interventions had an impact on the students' learning. They were also essential in establishing a base measure of the students' knowledge and understanding of the topic areas so that any change could be quantified. The number of marks for each topic was the same for both pedagogies.

To objectively measure the amount of improvement in performance between the pre- and post-tests for each topic, subtle changes were made to the post-test questions, allowing the student's specific knowledge to be assessed at each cognitive level. The post-test also contained five open-ended questions relating to student perceptions of the task completed; these are provided in Appendix D. A focus group was conducted at the end of each intervention (see Appendix E) and the analysis of these is presented in detail in the Results section.

3.8.1 Quantitative analysis techniques

The results from each intervention were compared to examine the nature of learning that occurred at different stages as instructed by the pedagogy. Interventions 1, 2 and 3 were analysed using the same techniques, with inferential statistics providing the basis for the analysis, primarily t-tests (both between-group and paired within-group). A series of five tests (outlined below) were conducted for each intervention and thus a Bonferroni correction was used to reduce the chance of obtaining Type I errors, i.e. to reduce the chance of at least one significant result occurring due to chance. For each of the five t-tests conducted in the quantitative analysis, an alpha (α) value of 0.01 was used.

Tests for normality were conducted on the five tests completed in interventions 1, 2 and 3 – fifteen in total – with the results shown in Appendix F. Values of skewness to standard error and kurtosis to standard error were calculated, with an absolute value was greater than one indicating the underlying data may not be normally distributed. Visual inspection of histograms of the results was also undertaken to determine whether the data was bimodal or obviously non-normally distributed. The results (presented in Appendix F) showed that, in general, the underlying data in interventions 1, 2 and 3 was normally distributed. Hence, t-tests were used to test each hypothesis.

Test 1: To ensure that the random allocation of students to each group did not result in one class being abler than the other, a between-groups two-sample t-test was used to compare the means of each students' combined pre-test performance results before the treatment was implemented. The results, to be presented later, suggest both groups in interventions 1, 2 and 3 were of equal ability.

Test 2: As there were two topics used in the GIS-based lessons (energy and development), it was also important to ascertain whether the student's prior knowledge of the topics might influence the results. Improvement scores for each student were calculated by subtracting pre-test scores from post-test scores for all lessons completed. Then a paired within-group t-test was used to compare the means between the improvement scores for each topic. For interventions 1, 2 and 3 it was found that there was no significant difference between the improvement scores for the Development topic or the Energy topic; these results are presented in the Results section.

Specific hypotheses were also presented as part of the broader research study and these were tested in each intervention and presented as Test 3 to Test 5.

Test 3 (Hypothesis 1): Hypothesis 1 sought to compare the total amount of improvement recorded for each student under direct instruction and guided discovery approaches. A paired within-group two-sample t-test was used to test the following hypothesis.

- $H1_{null}$: There is no difference in student improvement under direct instruction and guided discovery pedagogical treatments.
- $H1_{alt}$: There is a difference in student improvement under direct instruction and the guided discovery pedagogical treatments.

Test 4 (Hypothesis 2): Hypothesis 2 focused on comparing the means of improvement between each student's pre- and post-test lower-order thinking (LOT) results. LOT results were determined by combining each student's improvement results at the Remembering, Understanding and Apply levels, thereby creating a cumulative score. The combined pre-test results were then subtracted from the combined post-test results and the analysis was completed using a paired within-group paired t-test.

- $H2_{null}$: The GIS-based learning activities do not result in a change in students' lower-order thinking skills.
- $H2_{alt}$: The GIS-based learning activities result in a change in students' lower-order thinking

skills.

Test 5 (Hypothesis 3): Hypothesis 3 sought to compare the means of improvement between each students' pre- and post-test higher-order thinking (HOT) results. In this situation, however, the higher-order thinking results were calculated by combining each student's pre- and post-test scores at the Analyse, Evaluate and Create levels. The combined pre-test results were then subtracted from the combined post-test results and the analysis was completed using a paired within-group t-test.

- $H3_{null}$: The GIS-based learning activities do not result in a change in students' higher-order thinking skills.
- $H3_{alt}$: The GIS-based learning activities result in a change in students' higher-order thinking skills.

Thus, Test 3 (Hypothesis 1) addresses Research Question 1, relating to the impact of the pedagogical approach, and Test 4 and Test 5 address Research Question 3, relating to higher-order thinking. Whether ability level influenced the development of GIS thinking skills could be determined by determining whether there were significant improvements in lower-order thinking and higher-order thinking between interventions.

3.8.2 Qualitative analysis techniques

In this study, the analysis of the qualitative data involved several steps, including data collection, data analysis and report writing. These were not necessarily distinct steps in the process but, rather, occurred at the same time, as they were interrelated. This approach resembles the spiral image in Figure 11. In this way, it was possible to move in analytical circles, rather than adhere to a fixed linear approach (Creswell & Poth, 2017). Qualitative data, in the form of text and audio-visual material, was acquired and then, through the analytical process represented by the spirals, it was possible to emerge with an account, or narrative, of what had occurred.

This approach allows for data to be collected, questions to be posed and themes to be identified as part of the process. The themes were identified through the subjective interpretation of the content of text data; this involved a process of carefully analysing transcripts, identifying themes within the data sets and collating examples of those themes from the text. Using this process to identify themes, inferences were drawn and then examined. Different data sources were used in this analysis, including post-test open-ended survey questions and focus group interviews with the students. Following this, raw data was condensed into categories or themes using inductive reasoning. Despite this approach being flexible and non-linear, there are steps that need to be followed to ensure the approach is rigorous and able to withstand critical standards being applied (Creswell, 2014).

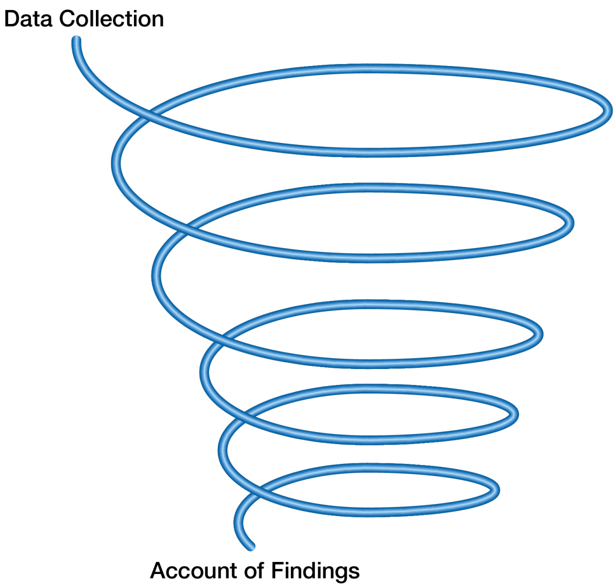


Figure 11. The Qualitative Content Analysis Spiral
Source: Adapted from Creswell & Poth (2017) by the researcher

Following Creswell's (2009) approach to data analysis and interpretation, there were four phases used in the qualitative content analysis in this study.

Phase 1 – Organisation

Phase 1 involved collating the files and artefacts from each intervention with each lesson recorded using a digital AV camera. Several open-ended survey questions also formed part of the post-test survey; these involved questions related to student perceptions and attitudes towards the lesson. These questions included what they enjoyed about the lesson, what they didn't, how the lesson could have been improved and how the GIS could have been used more effectively to assist them to better understand the topics of development or energy. The questions are noted in Appendix D.

The student responses to these questions were transcribed onto a Microsoft Word document for further analysis. After each intervention, a focus group was conducted with fifteen students for 30 minutes. The questions that formed the basis of the discussion were designed to draw out further information about the student's perceptions of the lessons, the approach undertaken, the role played by GIS and their suggestions about how to more effectively use GIS within the classroom (see Appendix E).

These focus groups provided the students with an opportunity to share their experiences, which, in turn, could potentially add value to the iterative redesign process and the research findings. The focus groups were videoed, and all student comments were transcribed onto a Microsoft Word document. Finally, an interview with the teacher was also undertaken.

All the data was imported into NVivo. One of the key strengths of using a program such as NVivo is that it can "sort and organise large volumes of qualitative data as well as store, annotate and retrieve text, locate words, phrases and segments of data, prepare diagrams and extract quotes" Creswell (1998, p.142). The qualitative data was collected and stored as an Internal 'Source' in NVivo as shown below in Figure 12.

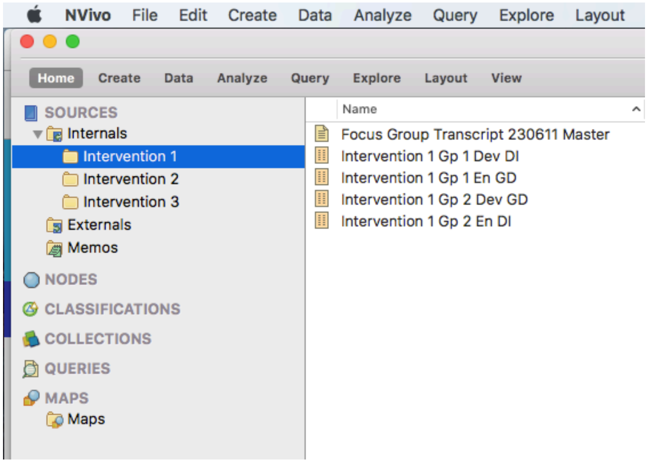


Figure 12. Qualitative data stored in NVivo

Figure 13 below the page shows how the responses to the open-ended questions in the post-test survey appear when stored in NVivo.

	ID	What did you like about the lesson	What didn't you like about the lesson	Do you have any other comments about the lesson
iam	Int1GpIDevDI 01	It was interactive as well as being discussion at times as well as individual work	Could have been more discussion, however, I understand why there wasn't.	Was good to have both instructions verbally and a step-by-step guide on the smart board.
t	Int1GpIDevDI 02	The ease of which maps could be manipulated.	The repetitiveness and the feel of being rushed in the work.	No
	Int1GpIDevDI 03	I learn't a lot about development that I didn't know.	Too rushed and quick to complete.	It was enjoyable.
ard	Int1GpIDevDI 04	I learnt about several other ways of measuring a person's wealth, such as HDI which I have not known before.	The time was a bit too short for me. I had to rush for some parts.	Overall it was pretty fun.
s	Int1GpIDevDI 05	It was interactive.	It wasn't fast enough.	N/A
	Int1GpIDevDI 06	I liked that it was interactive and it helped me to understand.	A lot of work with no break.	I feel GIS significantly helped in increasing my understanding of development and maps and patterns.
	Int1GpIDevDI 07	That there was so much information to look at.	It was very long.	The computers were good in showing different things.
	Int1GpIDevDI 08	I like that it is a hands-on exercise	I didn't enjoy how long it took.	No.
	Int1GpIDevDI 09	Clear instructions.	Too long. Very boring and not interactive enough.	I much prefer normal lessons.
	Int1GpIDevDI 10	I liked the fact that it was mostly using the computers so that we got a visual aid.	I didn't like the amount of writing that was required.	No, I thoroughly enjoyed it.
n,	Int1GpIDevDI 11	No.	No.	No.
lick	Int1GpIDevDI 12	The data was clearly displayed and easily accessible.	Some things were a little confusing to investigate on the screen.	No.

Figure 13. Example of post-test open-ended survey questions stored in NVivo

Phase 2 – Inspection

As outlined earlier, the primary qualitative data sources included the open-ended questions collected at the end of the post-test survey and the focus group interviews. This information was transcribed and imported into NVivo and then scanned to obtain a 'general sense' of the information and to reflect on its overall meaning. General thoughts were recorded as part of this process, allowing the researcher to start to understand the form and shape of the data and the general dimensions that may arise as part of the coding process.

Phase 3 – Classification

Phase 3 involved undertaking analysis of the information in NVivo by adopting a 'coding' process, "organising the material into chunks or segments of text before bringing meaning to information" (Kodish & Gittelsohn, 2011, p.53). The process involved drawing on the text that was transcribed from the surveys and focus group interviews during the data collection and then segmenting sentences and key terms into categories. These categories were labelled using appropriate terminology relating to the core questions of the study.

In NVivo, these core categories are referred to as 'nodes'; in this study, the information was organised according to the following nodes.

- **Lesson Features –** this included reference to resources, the interactive nature of the task, participant comments about the GIS software as well as the level of support and scaffolding provided in the activity. It also included reference to the resources and scaffolds used and the instruction booklet.
- **Pedagogical approach –** this included participant comments about the nature of the instruction used in each activity (guided discovery or direct instruction). Comments included student perceptions about the level of the teacher's involvement in the lesson and of the group work undertaken in the lesson.
- **Thinking skills and learning –** this refers to any observations or comments about the impact of the activities on the student thinking and the impact on their thinking. Comments included their perceptions of whether they felt engaged and whether their level of concentration was high/low, including feelings of being challenged and exposed to a new way of learning.
- **Suggestions for improvement –** this refers to any comments made by the participant in relation to ideas for improving the activity, including suggestions for additional support or instruction about how to use the GIS software.

This coding was used to interpret results from the qualitative analysis and determine strategies for redesign between iterations, rather than to form a theoretical or grounded model of the phenomena. Therefore, performing inter-rater reliability measurements was not deemed to be necessary in this instance – the primary measures of performance and outcomes related to the quantitative aspects of this study.

Phase 4 – Interpretation

The final step involved interpreting the data that was analysed; this information is presented in the Results section. The results were then compared against the research presented in the literature review and aligned with the results from the quantitative analysis. The purpose of this was to enable the key research questions and hypotheses to be addressed. Another important outcome was for key questions to be asked that may form the focus of future studies.

3.9 – Issues of validity

Issues of validity are concerned with the meaningfulness of research components and it was considered important to ensure that any concerns about the study were minimised and that the results of the study were credible (Drost, 2011). In this research, it was a priority to ensure that there was confidence that interpretations or inferences drawn from the results were valid and that were the result of the interventions applied in the study. Validity of the dependent and independent variables was also important because "if the variables of the study are not valid, then the study itself is not valid, and thus it is of little, if any, usefulness" (Gould, 2002, p.91).

There were two types of threat considered in this study.

Internal validity is essential for a design to have usefulness, as there must be confidence that the measured results of the study are in fact due to the effects of the treatment applied, and not some form of extraneous variable.

External validity considers the factors that enable the results to be generalised beyond the scope of the study and whether valid conclusions can be drawn from the specific to the general. Factors considered include the participant population, settings and procedures (Gould, 2002).

Several threats to internal and external validity for the quantitative and qualitative stage are outlined in Tables 11 and 12, as well as how these threats were addressed by the researcher.

Table 11. Threats to internal validity

Type of threat	Description of threat	Actions taken by researcher in response
History	Events during the study that can influence the results. These might include external events that could interrupt or disrupt the outcome of the intervention.	Students participating in groups during the intervention were isolated in a closed room so that exposure to external events between interventions was limited. The most likely identified distraction related to student concerns about work missed in other classes while each intervention was taking place. Student breaks during the interventions were also kept to a minimum. They were also asked to not interact with other students between iterations.
Maturation	Biological or psychological changes in participants during the study. The maturation threat in this study was tiredness as the study progressed.	Students were encouraged to ensure they slept well the night before the intervention and that they had consumed a healthy meal before completing the task. Water was also made available to them.
Testing	Pre- and post-tests that may be similar and participants become 'test-wise'. This is when they learnt something from the pre-test or can 'tune-into' the post-test because of their experience with the pre-test.	A 2 x 2 counterbalanced design was chosen as it reduces the effects of ordering. Also, attempts were made to ensure that the pre- and post-test, although similar, were varied enough to reduce the effects of students being able to 'tune-into' the post-test due to their pre-test experiences.
Instrumentation	Occurs when instrumentation changes between pre- and post-test. Care is needed to ensure one of the tests is not easier (or harder) than the other. Changes in the researcher 'as instrument' can also occur as they collect observations during each separate intervention.	Care was taken to ensure that the pre- and post-test were both of similar difficulty and this was tested in the pilot that was undertaken. Both supervisors also checked the instrumentation before the delivery of the interventions. Care was taken by the researcher to ensure that the process by which the observations taken was similar in all three interventions.
Selection Bias	Potentially the results of the study may be due to group differences and not necessarily to the treatment or the independent variable. Some students, for example, may be older and therefore more mature or more able.	Participants were selected from the same year group and were all boys. Participants were randomly allocated to balance out differences between groups. To esnure equal distribution, initial analysis was undertaken to check that groups were of approximate equal ability. A between-groups two-sample t-test was used to compare the means of the pre-test performance results before the treatment began. A check was made to ensure prior knowledge did not influence results. This involved calculating improvement scores for each student by subtracting pre-test scores from post-test scores for all lessons completed. Then, a paired within-group t-test was used to compare the means between the improvement scores for each topic.

Type of threat	Description of threat	Actions taken by researcher in response
Experimental Mortality	Participants dropping out during the study. If participants differentially drop out of the two groups, this can affect the results.	Every attempt was made to ensure participants did not drop out; however, there was an expectation that some would due to the nature of the daily routine of the school. The participants were also randomly assigned to each group, which (theoretically) meant that if drop outs did occur, there would be the same level of drop outs occurring between the groups.
Diffusion of Treatment	Treatment diffusion is a valid threat to internal validity, as it is not possible to prevent students (particularly in a school) talking among themselves. It is possible that students in one of the groups might share information to the participants in the other group. This would cloud the effect of the treatment.	The researcher encouraged students to not discuss the details of the intervention with students in the other group. Also, while taking observations during the intervention, care was taken to note whether there was any evidence, primarily via verbal comments, that the students had been given information from the other group that would in effect contaminate the results.

Table 12. Threats to external validity

Type of threat	Description of threat	Actions taken by researcher in response
Researcher bias	It is possible for the researcher to obtain results that are consistent with what they 'want to' find i.e. they have a bias towards the topic or research question.	The researcher engaged in critical self-reflection on their biases and predispositions, before and after each intervention. This was particularly relevant during the focus group interview. The researcher avoided leading questions that may influence the responses of the participants. Also, a mixed methods approach was adopted so data sources could corroborate each other, and quantitative analysis, which is less open to researcher bias.
Experimental Arrangement Settings	A factor when participants feel they are receiving special attention in a designated area in which treatment takes place.	The experimental setting was presented as much like a normal classroom as possible. The intervention was also completed in a way that most resembles a normal lesson.
Interaction of selection and treatment	Involves the researcher generalising results from these participants to others who do not have similar characteristics.	Care was taken to restrict suggestions that the results obtained from these students can be generalised to participants from different socio-economic backgrounds.
Interaction of setting and treatment	The experiment was performed in an independent school; there is the danger in generalising the results different settings, for example a different school.	Controlled by restricting broad claims that the results can be generalised to include all students. Clear reference will be made to the fact that the results were collected in an independent school.

Type of threat	Description of threat	Actions taken by researcher in response
Novelty or disruption effects	The treatment may yield positive results because the experiment is novel and the students feel special. The opposite may also be true; it disrupts routines and students may feel nervous or anxious.	The experiment is conducted in such a way that it resembles, as closely as possible, a normal class lesson. The researcher also ensured that the instructor (teacher) was known to the students and therefore this did not cause any anxiety for the students.
Experimenter effect	The effectiveness of the treatment may depend on the individual who administers the test, in this case the teacher. This is an important issue to control as the effect would not generalise to other situations.	Controlled by ensuring the instructor has the knowledge and skills to deliver the interventions effectively. The teacher chosen is well known to the students and the researcher spent considerable time preparing the teacher beforehand and ensuring that they could deliver the activities effectively.
Interaction of History and Treatment effects	Occurs when an experiment is conducted in a particular time with contextual factors that cannot be duplicated in another setting. This means that the treatment may not generalise to a different setting.	Care was taken by the researcher to not make broad claims that the findings can be generalised to participants from other school settings.
Interaction of Time of Measurement and Treatment effects	Relates to the timing, e.g. when the post-test is administered. May produce different results if the post-testing is immediately after the treatment as opposed to a few days afterward.	The post-test was administered at the same time in all three interventions, which was at the immediate conclusion of the student tasks delivered in the intervention.
Descriptive validity	Refers to the extent to which the account of the observations in the experiment as reported by the researcher are factual and accurate. This may be an issue if there is researcher bias.	Investigator triangulation was used involving the instructor to ensure that the observations are factual and accurate. Also, the researcher will work closely with the supervisors to ensure the descriptive reporting of the findings is valid.
Interpretative validity	Refers to the extent to which the research findings and experiences are interpreted correctly by the researcher and are portrayed accurately in the research report.	Researcher shares the interpretations of the participant's responses with other individuals including the instructor and supervisors (either qualitative in the form of open-ended questions or interviews or quantitative via, for example, Likert scale responses).
Theoretical validity	Refers to the degree to which a theoretical explanation is accurately produced from the findings of the research study and is therefore credible and defensible.	A detailed literature review was completed and was reflected upon once the study had been completed. Also, the researcher ensured that the participants and setting were understood clearly so that there is confidence in the patterns of relationships being observed.

3.10 Ethical considerations

In this study, special care was taken to ensure that the participation of the students was in accordance with Macquarie University's high ethical standards. Before each student participant in the sample population committed to be a subject in the study, they were notified of the aims, methods, anticipated benefits and potential hazards (such as tiredness or fatigue due to the nature of the intervention). They were also notified that they had the right to abstain from participating in the research and that they had the right to terminate their involvement at any time. The confidentiality of the individual's responses and comments was also guaranteed by the researcher. The dignity and privacy of every individual participant was respected by the researcher always. While each student participant was asked to provide general information relating to their age, identification of their cultural background was not requested.

No individual became a subject in the research without the prior consent of the participant and their parents/caregivers. There was no pressure or inducement of any kind offered to encourage them to become a subject in the research. The full identity of the individuals obtained during the research was kept confidential and no names were used in the subsequent write-up in this thesis. All data and research information collected during the research study will be kept secure by the researcher, with a copy of the data given to the primary and secondary supervisor (Ethics approval Ref No: 5201001530).

3.11 Limitations of the methodology

In this study it was not possible, or realistic, to draw on a large number of students within the year group. The Headmaster of the school made available a small number of classes so non-probability sampling was deemed to be the most effective approach. As a result, convenience sampling was utilised. The classes containing the student participants were the only students made available to the researcher. In this sampling technique subjects are selected because their recruitment was straightforward and it was not possible, in the context of a school, to widen the population.

Chapter 4: Results

This chapter provides a detailed summary of the results collected during the study. The data was collected according to the methodology and procedures outlined in Chapter 3 and the results were then processed in response to the central and sub-research questions posed in Chapter 1. The findings of each intervention (1, 2 and 3) are presented sequentially in this section, with the quantitative results presented before the qualitative findings. In presenting the results in this way, it is possible to carefully describe the outcomes of each intervention and the effects of the GIS-based activities introduced in each iteration. The results are objectively discussed throughout the structure and summaries of the findings are provided at the end of the chapter. Relevant data is also presented in Appendices F to H.

4.1 Intervention 1 results

Intervention 1 was undertaken with students of middle ability. The quantitative results were collected and subsequently analysed as per the techniques outlined in the methodology.

4.1.1 Quantitative results

Test 1 – Comparing ability levels of each group

To ensure that the random allocation of students to each group did not result in one class being more able than the other, a between-groups two-sample t-test was used to compare the combined means of the pre-test performance results before the interventions began.

For Intervention 1, there was no significant difference between Group I's combined pre-test scores ($M=52.941$, $SD=11.421$) and Group II's combined pre-test scores ($M=50.063$, $SD=9.125$); $t(31)$, $p=0.432$ (two-tailed). These results suggest that both classes established for Intervention 1 were of equal ability.

Test 2 – Influence of prior knowledge

As there were two topics used in the GIS-based lessons (Energy and Development), it was also important to ascertain whether a student's prior knowledge of the topics might influence the results. Improvement scores for each student were calculated by subtracting pre-test scores from post-test scores for all lessons completed. Then, a paired within-group t-test was used to compare the means between the improvement scores for each topic.

For Intervention 1, there was no significant difference between the improvement scores for the Development topic ($M=2.909$, $SD=4.798$) and the improvement scores for the Energy topic ($M=5.364$, $SD=4.911$); $t(32)$, $p=0.075$ (two-tailed).

These findings suggest that there was no influence of prior knowledge on the results of Intervention 1.

Test 3 – Hypothesis 1

As noted in the study's methodology, Hypothesis 1 sought to compare the total amount of improvement that was recorded for each student under direct instruction and guided discovery approaches. A paired within-group two-sample t-test was used to test the following hypothesis.

- $H1_{null}$: There is no difference in student improvement under direct instruction and guided discovery pedagogical treatments.
- $H1_{alt}$: There is a difference in student improvement under direct instruction and the guided discovery pedagogical treatments.

This two-tailed (directional) hypothesis was tested at a one per cent level of significance ($\boldsymbol{\alpha}=0.01$) using a paired within-group two-sample t-test. There was no significant difference between the means of the improvement for direct instruction ($M=4.242$, $SD=5.075$) and guided discovery ($M=4.030$, $SD=4.946$); $t(32)$, $p=0.881$ (two-tailed). Therefore, the type of pedagogy used in the lessons of Intervention 1, Direct Instruction or Guided Discovery, did not appear to influence student performance in the tests.

Test 4 – Hypothesis 2

Hypothesis 2 focused on comparing the means of improvement between each student's pre- and post-test lower-order thinking (LOT) results, calculated using the method outlined in the methodology section. A within-group paired t-test was used to measure improvement and test the following hypothesis.

- $H2_{null}$: The GIS-based learning activities do not result in a change in students' lower-order thinking skills.
- $H2_{alt}$: The GIS-based learning activities result in a change in students' lower-order thinking

skills.

In Intervention 1, there was a significant difference between the pre-test results (M=28.152, SD=5.386) and the post-test results (M=36.091, SD=4.869); t(32), p<.001 (two-tailed), suggesting that the GIS-based activities were effective in improving the lower-order thinking skills of the middle-ability students in this intervention.

This finding is important, as the students produced improved results from pre- to post-test, which suggests that learning has taken place at this level and that GIS-based activities improve learning outcomes at the lower-order level.

Test 5 – Hypothesis 3

Following the same approach as adopted for Test 4, which tested Intervention 1 Hypothesis 2, Intervention 1 Hypothesis 3 sought to compare the means of improvement between each students' pre- and post-test results, but at the higher-order thinking (HOT) level. The combined pre-test results were then subtracted from the combined post-test results and the analysis was completed using a paired within-group t-test.

- $H3_{null}$: The GIS-based learning activities do not result in a change in students' higher- order thinking skills.
- $H3_{alt}$: The GIS-based learning activities result in a change in students' higher-order thinking skills.

For Intervention 1, there was no significant difference calculated between the pre-test results (M=23.394, SD=6.031) and the post-test results (M=23.727, SD=4.817); t(32), p=0.741 (two-tailed). From this it can be concluded that there was no improvement in the higher-order thinking skills (HOTs) of the middle-ability students who completed this intervention.

In summary, the quantitative results of Intervention 1 showed that middle-ability students were deemed to be of equal ability and that there was no influence of prior knowledge on the results. It was also shown that neither pedagogical approach used in Intervention 1 (either direct instruction or guided discovery) had a stronger influence on student performance in the tests than the other. Also, the student's results at the three lower-order thinking levels (Remember, Understand and Apply) showed improvement from pre- to post-test, indicating that the activities had an impact on learning outcomes at this level. This improvement suggests that the nature of the GIS-based learning tasks adopted enabled the students to engage their lower-order thinking skills. A key finding of Intervention 1, however, was the fact that there was no noticeable improvement in learning outcomes at the higher-order thinking level (Analyse, Evaluate and Create) between the pre- and post-test. This lack of improvement suggests that the GIS-based activities did not engage the students higher-order thinking skills. As a result, the nature of the pedagogical instruction delivered in Intervention 1 should be carefully reviewed to consider whether there are deficiencies or limitations in the approach that prevent the engagement of higher-order thinking skills in middle-ability students.

4.1.2 Qualitative results

As noted in the methodology, several types of qualitative data were collected in this study. Student responses recorded in the open-ended questions of the post-test survey were analysed and, using an inductive approach, a focus group interview was also undertaken with a randomly selected group of students (post-treatment) to draw out their perceptions of the interventions in which they participated. Analysis involved organising student responses into themes using NVivo 11, as discussed in the methodology.

4.1.2.1 Survey and focus group interview results

Student thoughts and perceptions about the study, drawn from post-test survey questions and focus group interviews, were recorded, transcribed and analysed using NVivo. The process involved identifying broader dimensions that related to key themes (or nodes) relevant to the research questions and as such the student's responses were analysed accordingly. These are outlined in detail in the methodology and include:

- lesson features;
- pedagogical approach;
- thinking skills and learning; and
- suggestions for improvement.

The student's qualitative comments in Intervention 1 provided an insight into their thoughts about the **lesson features**.

Several students had positive perceptions about the way in which GIS software could effectively represent information. For instance, one student noted:

> I think GIS is good. It's pretty amazing how everything is just stored in one little map. Anything you want to know about a country is like there in front of you. I think it is really good.

Another student observed that:

> It's always really good how there's the information tool and you click on any country you want and it comes up with the name as well as other information – the shape of the country, the population, lots of information about it.

As noted in the methodology, there were several tools within the ArcGIS software that were engaged to support student thinking during the activity. These specifically allowed the students to visualise and interpret the data displayed in different ways, as noted by one student as follows:

> I found the swipe and the flicker tool made it a lot easier to compare trends because instead of clicking from one to the other and waiting for it to load, it was already just turned on – this was the quickest way to look at it.

For some, there was a sense that the software tools and menu items could have been more effectively organised to support them in completing the task. Several comments were made by students such as:

> Having all the tools at the top of the program would have been better as then you wouldn't have to click on the toolbar to bring it all up. Best to have everything there at the top.

Another simply commented "Perhaps there could be other ways of comparing data".

There were some limitations noted by the students in terms of the organisation of the lesson. Some found time pressures during the task, while others felt the task was too long. Other students made general observations about the repetitive nature of some questions.

The **pedagogical approach** was also a key point of discussion for the students. In the first instance, it was clear that the students recognised the differences between the two pedagogical approaches – direct instruction and guided discovery. One student noted, "In the first lesson, the teacher took us through the instructions but in the second one we were on our own".

There were several positive comments for both the direct instruction and guided discovery approaches. With respect to the guided discovery approach, there was clear support for working in groups, including one comment that "There was more to discuss when you were in groups. It was good to be able to discuss your opinion with someone else". Others noted "I liked that we got to work in groups and share ideas with each other".

The notion of being able to discuss the task with a partner was again acknowledged by another student:

> I was with a good partner and I found it better to be able to talk with him about what we were doing. It was a lot easier to understand this way and we shared our knowledge of the topic.

There were also negative comments about the characteristics of the Guided Discovery approach, including that group work may slow down more capable learners:

> I found the group approach less interesting because my partner was less able than me so I ended up having to explain to him what he needed to do. He held me back.

There were also comments that were generally in support of characteristics of the direct instruction approach, and some noted that "This approach [DI] was quicker because you were on your own and you had more support from the teacher". Another commented:

> You could work much faster when the teacher was telling you what you had to do because you didn't have to investigate different aspects beyond what you needed to write about.

As was the case with the guided discovery approach, there were several negative comments about the characteristics of the direct instruction pedagogy. These included comments about the nature of the instruction and how the student felt about the task, such as "I did not like just following the instructions. It was tedious".

One student suggested that further opportunities to interact with the task may have had a greater impact on student engagement, suggesting "If there was more interaction it would have drawn on student's interest more as they could do more themselves". Another commented, "In the lesson when you were on your own [DI], you felt kind of rushed".

Of interest was the suggestion by some students to merge characteristics of both approaches, including one student commenting, "I think you should have a combination of both approaches. If you have just straight forward instruction, it gets very boring".

The view that the direct instruction approach was boring was also supported by other participants who made comments including:

> I think you could have a mix of teaching styles where we were in groups but you had guidance from the teacher. It got boring when you were on your own and you were being told what to do.

There were also numerous references to **thinking and learning** in the focus group. Several students commented on the more open-ended higher-order thinking questions at the end of the task which, they suggest, made them 'think'. There were several observations noted about the tasks in the latter stages of the activity, which were designed to be more challenging. These included comments such as "The last questions required us to write longer responses. They made us think more rather than just writing down facts", while others noted:

> You had to think more with the questions at the end. The first few questions were mainly definitions and required you to write down information. The last few questions were more about strategies that you would use.

Another student noted:

> The questions at the start were boring. I liked the questions when we were asked to imagine we were someone in a scenario and then you had to suggest what you would do.

There was clear acknowledgement by some students that what they were doing in the lesson was enhancing their learning of the topic. An example of this is as follows:

> I think the scenario questions got you to think more about the topic as they actually got you to look at the map and analyse the data. Then you had to use the information to come up with strategies rather than just stating what the data says like the earlier questions.
>
> You learnt things about China and I thought it would be definitely developing. It has a billion people but then the map suggests that it's developing. The maps for Russia and China were similar in some respects and this was a bit weird.

Some commented on the interactive nature of the task and the effect that this had on their level of engagement, including "I liked that it was interactive and it helped me concentrate".

It was noted by some that the technology played a part in supporting their learning:

> I thought it was like 'ok, this is the question. Now, how do I find out information that I need to answer it?' So, for me thinking about the technology helped me to work out what the answer was.

The final theme to emerge from the Focus Group related to **suggestions for improvement**. Some suggested that it would have been helpful to have been shown some of the GIS tools to use, possibly at an earlier point:

> I think it would have been better if we were shown some different tools that we could use. Then we could have been told to go and use whichever one we wanted and discover which one was easiest to compare some of the different data.

Another commented about the potential to draw upon, or utilise, other data sets within the GIS with statements such as "Perhaps there could have been other ways of comparing the data". This sentiment was supported by other participants who also noted that further explanation of how the GIS tools worked would have been of benefit to them:

> Well the GIS program is really good but I think like we should have had more explanation about how each tool worked and which tool could have been used to analyse the data.

The suggestion for more explicit instructions was noted by others as well with one student simply commenting "More step-by-step instructions on how to use the GIS would have been good".

One student suggested that they would have liked to have had laptops open alongside the desktop computers on which they were completing the GIS activity, possibly to practice using the GIS software.

> It would have been helpful to have our laptops while we're looking at the GIS and the teacher was up the front showing us what to do and how to use the program.

Some students suggested that additional knowledge about the topic could have been used to further support them learning in the task. Comments such as this support this notion including "More information about the history and background of the issue would have been good" and "I think it was done well, however, we could have done further internet research to further investigate the topic".

In addition to this, there were several comments referring to the use of images and how they might enhance the learning experience so as to provide greater understanding about the topic. One noted, "Maybe embedding some images of what the country actually looked like would have been good. This would have given us a better understanding of what goes on" while others discussed the need for more images, or visual aids, to inspire them further with comments such as "More variety of visual aids besides the maps to promote inspiration". Others noted, "More examples of real world situations including pictures and statistics" while some suggested further support for visual aids would have been of value: "If we had been given more visual examples and demonstrations I believe it would have been better".

There were also several requests for the use of videos to support their learning, including one who noted, "I would have wanted a video about energy to enlarge my view of it" and "By adding a video option so we can get a broader view of the topic we are learning about".

In summary, several observations can be noted from the qualitative results recorded for Intervention 1.

In relation to the lesson itself, the qualitative results suggest that the students found the GIS-based activities overall to be engaging and generally enjoyable. It was clear that they could access the information about each topic in the GIS program and found the variety of tools useful, although it was noted that further guidance about other tools that could have been used to explore the data would have been useful. It was evident in the responses that the visualisation tools of the GIS were valued by the students and the ability to explore the GIS data to answer the question was also a key positive feature.

In terms of the pedagogical approaches adopted in Intervention 1, the qualitative results suggest affordances with both pedagogical approaches – direct instruction and guided discovery. In relation to the guided discovery approach, students commented generally on the fact that working with a partner in a group allowed the sharing of ideas and discussion of the issue being investigated. It also enabled the pair to work through any problems that they had about how to use the GIS to answer the questions. Similarly, there was a general sense that the direct instruction approach enabled the task to be completed quickly particularly the teacher providing clear instructions.

The qualitative results also indicate that the students found the higher-order thinking questions the most engaging. These were the questions used in the latter stages of the activity and were open-ended in nature and included scenarios or hypothetical situations. These questions appeared to engage students more effectively than the closed questions in the early stages of the task. It was clear the students found these LOT questions more repetitive and less challenging. There was also strong evidence to support the notion that the GIS technology provided the students with the information and level of detail needed to answer the questions in the latter HOT questions of the task.

There were also several suggestions about how to improve the GIS-based activity. There was a strong sense that the students found some aspects of the different tasks tedious and, at times, repetitive, and this should be addressed in the future. It was suggested that future activities should provide clearer instructions about how to use the tools of the GIS to answer the questions provided in the worksheet. There is also evidence that the students would have liked to have been shown other tools to explore the data in the GIS. It was very clear that students wanted information in addition to that provided in the activity to answer the question, including embedded images and videos about the topic. The students indicated a clear sense that elements of the lesson were repetitive and tedious, so future iterations of the activity should be modified accordingly.

4.2 Intervention 2 results

Intervention 2 was then implemented for students of high ability. To confirm that the students in Intervention 2 were of higher ability, an initial between-sample t-test was used to compare the sum of each student's two pre-tests recorded in Intervention 1 with the sum of the two pre-tests recorded by students in Intervention 2.

The results of the between two-sample t-test showed there was a significant difference between the combined pre-test results for Intervention 1 ($M=51.545$, $SD=10.314$) and the combined pre-test results for Intervention 2 ($M=63.175$, $SD=8.382$); $t(71)$, $p<.001$ (two-tailed). This finding suggests that the students who participated in Intervention 2 were of higher ability than those who participated in Intervention 1.

The quantitative results for Intervention 2 were collected and subsequently analysed as per the techniques outlined in the methodology.

4.2.1 Quantitative results

Test 1 – Comparing ability levels of each group

As with Intervention 1, an attempt was made to check that the random allocation of students to each group did not result in one class being of higher ability than the other. A between-groups two-sample t-test was used to compare the combined means of the pre-test performance results.

For Intervention 2, there was no significant difference between Group I's pre-test results ($M=64.087$, $SD=8.549$) and Group II's pre-test results ($M=61.941$, $SD=8.242$); $t(38)$, $p=0.431$ (two-tailed).

These results suggest that both Intervention 2 classes were of approximately equal ability, and of higher ability than Intervention 1.

Test 2 – Influence of prior knowledge

The student's prior knowledge was again considered to determine whether this influenced the results, with a paired within-group t-test used to compare the means between the improvement scores for each topic.

As was the case with Intervention 1, there was no significant difference between the improvement scores for the Development topic ($M=7.925$, $SD=4.758$) or in the improvement scores for the Energy topic ($M=9.7$, $SD=4.256$); $t(39)$, $p=0.039$ (two-tailed). These results suggest that there was no influence of prior knowledge on the Intervention 2 results.

Test 3 – Hypothesis 1

In Intervention 2, the results of the paired within-group two-sample t-test used to test Hypothesis 1 showed no significant difference, being recorded between the means of improvement using direct instruction ($M=8.675$, $SD=4.299$) and guided discovery ($M=8.95$, $SD=4.883$); $t(39)$, $p=0.790$ (two-tailed). As was the case in Intervention 1, neither pedagogical approach (direct instruction and guided discovery) influenced student performance in Intervention 2.

Test 4 – Hypothesis 2

The results of the paired within-group two-sample t-test used to test Hypothesis 2 showed a significant difference between the pre-test results ($M=35.075$, $SD=4.190$) and post-test results ($M=44.2$, $SD=3.891$); $t(39)$, $p<.001$ (two-tailed). Again, this suggests that the GIS-based activities were effective in improving the lower-order thinking skills of the students who participated in this intervention. These findings indicate that there was an improvement in middle- and higher-ability students' LOT skills after completing each intervention. This is an important result, as both groups of students produced improved results from pre- to post-test, providing further evidence that the GIS-based activities improved student's thinking at the lower-order thinking level.

Test 5 – Hypothesis 3

In contrast to Intervention 1, the results of the paired within-group two-sample t-test used to test Hypothesis 3 showed a significant difference calculated between the pre-test results ($M=28.1$, $SD=5.007$) and post-test results ($M=36.6$, $SD=4.081$); $t(39)$, $p<.001$ (two-tailed). This finding suggests that the higher-order thinking skills of the higher-ability students in this intervention were developed as a result of completing the GIS-based intervention. This is an important result in the context of this study and encourages further examination of how HOT skills of middle-ability students might be improved from pre- to post-test.

In summary, the quantitative results of Intervention 2 showed that high-ability students were deemed to be of equal ability and that there was no influence of prior knowledge on the results. As was the case in Intervention 1, it was also shown that neither pedagogical approach used in Intervention 1 (direct instruction or guided discovery) had a stronger influence on student performance in the tests than the other. As was the case with Intervention 1, the results of Intervention 2 also showed that the GIS-based activities resulted in improved learning outcomes at the lower-order thinking level from pre- to post-test. This improvement suggests that students' lower-order thinking skills were engaged, as was the case with the middle-ability students in Intervention 1. A key finding of the results in Intervention 2, however, was the fact that, unlike the middle-ability students who completed Intervention 1, there was in fact a noticeable improvement in learning outcomes at the higher-order thinking level, again suggesting that the GIS-based activities completed by the students did engage their higher-order thinking skills. This finding further emphasises the need to examine more carefully how to use GIS-based activities to engage the higher-order thinking skills of middle-ability students.

4.2.2 Qualitative results

4.2.2.1 Survey and focus group interview results

For Intervention 2, with the high-ability students, the participants were again willing to share their thoughts about the **lesson features**.

As was the case in Intervention 1, students had positive views about using the GIS software and the way in which the GIS could present information about the topic in visual form, including comments such as "The patterns were really helpful in me understanding the topic. It broadens your knowledge a lot more when you learn visually like that".

Students again noted the value of having a large amount of information accessible and in the one place within the GIS, with comments including "The information in just one program is great. All the information that you could see was there".

Others commented on the interactivity of the program and the visual tools that aided interpretation of understanding with statements such as "I though the GIS was very easy and interesting to use.

It showed me patterns in countries that I hadn't seen before and it gave me a better understanding of the world".

One student noted that the GIS was a more efficient resource than others, such as the Internet, suggesting, "I thought that all the information was there and all you had to do was click one button and get a totally different map. It made it more efficient instead of looking at Google etc".

As was the case in Intervention 1, comments were made about the *Swipe* and *Flicker* functions that students were expected to use to support their learning in the task. One noted, "I liked how you could use the flicker tool and the swipe tool to move it up so you could compare different bits of information".

The ability to visualise the information about each topic was a key point of discussion for some, and one student who just completed the topic of development commented, "It gave me a good visual representation and this allowed me to see clear patterns".

Further support for the visualisation tools of the GIS was expressed by others, including one student who suggested, "In general, it was interesting and I felt that the GIS helped me greatly to understand patterns in development and inequalities in our world".

There were some criticisms of the lesson features, similar to those offered by students in Intervention 1. These included references to occasional technical issues with the GIS software, although there were no further comments about the repetitive nature of the questions or their length in the focus group discussion. The absence of such comments suggests that the minor adjustments made following Intervention 1 may have improved the quality of the instructional materials.

As for Intervention 1, the level of teacher involvement in each **pedagogical approach** was noted by students, demonstrating that students recognised the distinct differences between each method of instruction. One noted, "The first lesson was more of the teacher telling us what to do and they walked us through the task. In the other lesson, we were allowed to work through the questions with our partner". Another also suggested that "The teacher had a much bigger role in the first one. They explained some of the concepts better. The other lesson was like 'Find this and if you have any problems talk to your partner'".

While the level of instruction offered by the teacher was a positive for some, others felt that there were also limitations with, for example, the direct instruction approach, as it was too restrictive.

One commented that “When you had a partner, there was more freedom. With the other one it was like stop and wait – sometimes you got bored and wanted to go on”, while another noted:

> In the group task, we were working in pairs and we pretty much were able to go ahead and then see where we were at. It had less teacher involvement and we could do it ourselves. In the other lesson [DI], we had to work by ourselves and we were not really allowed to go ahead.

The ability to draw upon the insights of a partner was welcomed by some:

> I thought that in the group task it was helpful to have a partner. You could talk back about things and your partner might come up with an idea that you hadn’t thought of and it also meant that you got the questions much quicker and learnt more.

There was a strong sense that the high-ability students embraced the direct instruction approach. Five students made positive comments about the approach, including comments suggesting they appreciated having the instructions clearly set out for them. Comments included “I really liked that there were clear instructions and then the teacher would go over it to make sure you understood it”, while another suggested that “The teacher had a bigger role and this aided the entire learning experience”. Also, one student suggested that “The way that the teacher walked us through the work step by step was helpful”.

Two students commented negatively about the direct instruction approach with reference to the restrictive nature of the instruction and the level of teacher involvement. Comments included “In this lesson, you were shown what you needed to know but you were limited to just that. You couldn’t explore other things to expand your knowledge”. Another provided more detail:

> In the individual one [DI], the teacher was talking so much that you couldn’t get a question in because he would just continue giving information; even if you wanted to ask a totally different question about an unrelated topic.

One student provided positive comments about the impact of the teacher’s involvement in the lesson. Their comments suggest that the direct instruction approach provided a sense that they were progressing at the same pace as the other students.

> When using GIS, it’s much better with the teacher directing because in the group task if there were problems the teacher would have to go around, but with the teacher-led one everyone was at the same point.

There were numerous comments from students related to **thinking skills and learning**. Some emphasised the positives of using a technology such as GIS rather than more traditional didactic approaches, with comments including “I found that I learnt a lot better from the GIS than I do from listening to a teacher or reading from a book. It was a lot more interesting to learn from so it stuck in my head”.

Some students suggested a link between the type of questions and the impact this had on their ability to think:

> I thought that the more direct questions were a bit too easy. It pretty much told you the answer, particularly when it asked you to compare two layers for example. I thought that the open-ended questions were better because it made you think more about it.

Three students also referred to the fact that they found the scenario-based activities helpful in their learning; comments included “The scenario style questions were valuable in helping you to think about what you were doing and I liked that it was something in reality”.

It was also noted that there was a progression of learning in the task, with each question building on the previous questions. Comments included “The extended style questions kind of needed the knowledge of the other questions to complete them”, and also “By having the longer questions at the end, you sort of had to build on everything you had done before”.

In terms of suggestions for improvement, several students provided their thoughts, particularly in relation to the way the GIS data was presented and their ability to interpret the information:

> Sometimes the layers were confusing to understand because they’re like not always the same. It would be helpful if it told you where some of the patterns were or you were shown what to do.

Others noted their preference to be given clearer instructions about how to use the GIS tools to interpret the information presented in the GIS more effectively:

> It would have been good if we had been given an example of ‘this is an example of a relationship here and there’ and this would have prompted us to look for similar things or variations like it.

There were clear suggestions about being shown how to use specific GIS tools that were relevant to the activity, including “It would have been good to have had a few minutes before the lesson to be shown how to use the GIS tools”.

Reference to issues of cognitive load in relation to learning a tool in conjunction with knowledge about a topic was noted by one student:

> It would have been good to have had prep set to learn about the topic before we did the activity. There was almost too much info to look at. Going home to look at layers then come back to class would have been good.

There were numerous comments from students wanting more explicit instruction about how to use the GIS. Examples of this include the following:

> Better instructions about how to use the GIS would have been good" as well as "The teacher could have demonstrated what to do more clearly. It was difficult to work out and understand how to use the GIS.

Two students felt a more concise approach was needed, with comments such as "We could have been shown the top 5 functions that we were going to use in the lesson. That would have been really helpful" and "Using more functions of the program would have greatly enhanced the learning experience".

It was clear that many students who completed Intervention 2 were seeking more explicit guidance about how to use the GIS software. This was a strong sub-theme that emerged, with at least six students suggesting that instructional videos would have been valuable in the lesson. Comments included "An introduction with more information about the skills and functions of the GIS, and how to use them, would have been really helpful". Others noted that "Visual representation like a short video about how to use the GIS tools would have been good" and "Possibly having a few videos explaining how to use the tools of the GIS".

As was the case in Intervention 1, some students suggested that additional approaches could have been adopted to provide further information about the topic. Two students noted that they would have liked there to have had pictures embedded into the GIS project and multimedia videos, with one suggesting, "I think embedded videos and pictures would have made the lesson more interesting" as well as "The use of multimedia, other than GIS, would have been good". Another noted:

> Improved discussion between members of the class would have been good. The lesson could have incorporated more visual/multimedia aids. Also, we could have done more research in the library about the topic first or even discussed the topic of Energy with the Science faculty.

Another student suggested that the lesson should be “Split over two or three lessons with research tasks for homework that go into more detail”.

With regard to Intervention 2, several key observations can be noted from the qualitative results. It was again clear that students who completed Intervention 2 found the lesson to be engaging and there was a perceived value in using the GIS. The high-ability students in this intervention also referred to the way the GIS provided a powerful visual representation of the data relating to the topic and how this helped them understand the topic being investigated. It was clear they could use the GIS functions to compare information in the datasets and that this was helpful to them in being able to interpret the information and topics they were investigating.

In terms of the pedagogical approaches adopted in this intervention, the higher-ability students provided support for both approaches and appeared to favour the direct instruction approach. The higher-ability students seemed to be clearer in their descriptions and it was evident that they valued the explicit instruction offered by the teacher in the direct instruction model, as well as the opportunity to work quickly and independently through the task. They also appreciated the less explicit support offered in the guided discovery approaches, and the group work in which they could share ideas with and get support from their partner.

Regarding student thinking, the students were open in noting that the GIS enhanced their learning experience. The higher-ability students in Intervention 2 also commented on the types of questions that were presented in the activity, with the open-ended questions providing a greater challenge. It was clear that many of these high-ability students felt the closed questions in Part A, B and C of each activity were less challenging and engaging. There was a strong sense in the comments that the knowledge acquired in earlier parts of the module (lower-order thinking questions) enabled the students to answer the more difficult scenario-based higher-order thinking questions in parts D, E and F.

As suggested in Intervention 1, some minor modifications were made to the level of detail of some questions in Intervention 2 to ensure the students could complete the task efficiently. These modifications appeared to have had the desired effect, as there were significantly fewer comments made about the fact that the questions were repetitive. There were again several suggestions from the students to include some additional multimedia (both pictures and videos) to enhance the learning experience. A few students recommended including opportunities for additional research before the GIS lesson took place, and this is a useful recommendation for future reference. There was a strong sense that there was a distinct lack of instruction before and during the lesson about how to use the tools and functions of the GIS. Several suggestions were offered by the high-ability students, including a request to provide videos of how to use the GIS.

4.2.2.2 Comparison of qualitative comments from Intervention 1 to Intervention 2

When comparing and contrasting the qualitative comments from the middle-ability students in Intervention 1 to those of high-ability students in Intervention 2, there were several observations that should be noted.

It was clear that both groups of students found the lesson to be valuable and that the GIS enhanced their learning experience. There was a strong sense that they enjoyed using the technology and would enjoy further opportunities to use the GIS in their geography lessons. It was also clear that the high-ability students in Intervention 2 favoured the direct instruction approach over the guided discovery approach. This view contrasted with the students in Intervention 1, who showed no preference for either approach. In both interventions, the instructional approaches (direct instruction and guided discovery) were considered worthwhile and allowed them to engage with their learning about the topic and thinking. Both middle- and high-ability students valued the support provided by the teacher, although it can be noted that the higher-ability students provided more detail when describing the comments about the level of teacher involvement. It was clear that some students (particularly those high-ability students in Intervention 2) appreciated the direct, explicit instruction of the teacher in the DI approach but they also valued the supporting role that they offered in the GD approach. There was also a strong sense that the students appreciated the opportunity to share their ideas with their partner, and that this also helped them to understand the topic that they were exploring.

The open-ended questions that formed the basis of the higher-order thinking sections of the GIS-based activity were particularly noted by both groups as being engaging and generally more interesting than the closed questions that comprised the lower-order thinking sections. They also noted that they could build upon the knowledge acquired in the earlier sections of the activity, whereas there was little or no reference to that effect from the middle-ability students who completed Intervention 1.

Both groups of students made strong suggestions to include more multimedia (other than the GIS) in the activity in the form of embedded images or videos that they perceived would enhance their learning experience. The students from both cohorts also felt that more explicit instruction about how to use GIS was required. It was also noted that the higher-ability students who completed

Intervention 2 specifically requested clearer instructions be given to them about how to use the GIS, with some suggesting that this could be delivered in the form of a video.

4.3 Intervention 3 Results

4.3.1 Quantitative Results

In Intervention 3, additional scaffolding was implemented at the higher-order thinking level to help students engage more effectively with the higher-order thinking questions (the parts relating to analysis, evaluation and creativity). As noted in the methodology, three multimedia (video) screencasts were developed in the direct instruction approach, with each video showing the students how to use the GIS functions to complete the tasks at the Analyse, Evaluate and Create cognitive level. The students who completed the guided discovery approach received similar instructions; however, these were not delivered through a multimedia screencast but by the teachers themselves. This delivery style was adopted because the middle-ability students struggled to effectively answer the HOT questions in Intervention 1 and there was a specific recommendation from the higher-ability students who completed Intervention 2 to provide explicit scaffolding in the form of instructions on how to use the tools and functions of the GIS to answer the questions.

As was the case with the previous interventions, the quantitative results were collected and subsequently analysed as per the techniques outlined in the methodology.

To begin, however, a between-sample t-test was used to compare the sum of the students' pre-tests recorded in Intervention 2 with the sum of their pre-tests in Intervention 3. This comparison was to verify that the students in Intervention 3 were, in fact, of middle ability compared to those who participated in Intervention 2, who were of high ability.

The results of the between-sample t-test showed that there was a significant difference between the combined pre-test results for Intervention 2 (M=63.175, SD=8.382) and the combined pre-test results for Intervention 3 (M=47.148, SD=8.361); t(65), p<.001 (two-tailed). This difference suggests that the students who participated in Intervention 3 were less able (middle ability) than those who participated in Intervention 2 (high ability).

Similarly, a between-groups two-sample t-test was used to compare the sum of each student's two pre-tests from Intervention 1 and Intervention 3 to check that they were of equal middle ability.

The results of the between-sample t-test showed that there was no significant difference between the combined pre-test results for Intervention 1 (M=51.545, SD=10.314) and the combined pre-test results for Intervention 3 (M=47.148, SD=8.361); t(58), p=0.079 (two-tailed). This finding suggests that the students who participated in Intervention 1 and Intervention 3 were of similar middle ability.

Test 1 – Comparing ability levels of each group

As with interventions 1 and 2, a test was undertaken to confirm that the random allocation of students to each group did not result in one class being abler than the other. As such, a between-groups two-sample t-test was used to compare the combined means of the pre-test performance results. This comparison revealed no significant difference between Group I's combined pre-test results (M=48, SD=7.264) and Group II's combined pre-test results (M=46.231, SD=9.619); t(25), p=0.593 (two-tailed).

On this basis, it is suggested that there is no difference in the ability levels of the two groups.

Test 2 – Influence of prior knowledge

The results of the paired within-group t-test comparing the means of the improvement scores for each topic are as follows.

As was the case with Intervention 1, there was no significant difference between the improvement scores for the Development topic (M=10.618, SD=5.003) and the improvement scores for the Energy topic (M=12.5, SD=5.299); t(33), p=0.050 (two-tailed). These results suggest that prior knowledge did not have an influence on the result.

Test 3 – Hypothesis 1

The results of the paired within-group two-sample t-test used to test Hypothesis 1 showed there was no significant difference between the means of improvement using direct instruction (M=11.588, SD=4.652) and guided discovery (M=11.529, SD=5.769); t(33), p=0.953 (two-tailed). As was the case in interventions 1 and 2, neither pedagogical approach (direct instruction and guided discovery) influenced student performance in Intervention 3.

Test 4 – Hypothesis 2

The results of the paired within-group two-sample t-test used to test Hypothesis 2 showed there was a significant difference between the pre-test results (M=29.353, SD=5.057) and post-test results (M=41.618, SD=4.652); t(33), p<.001 (two-tailed). Again, this suggests that the GIS-based activities were effective in improving the lower-order thinking skills of the students who participated in this intervention.

Test 5 – Hypothesis 3

As was the case with Intervention 2, the results of the paired within-group two-sample t-test used to test Hypothesis 3 showed that there was a significant difference calculated between the pre-test results (M=19.059, SD=5.222) and post-test results (M=29.912, SD=2.927); t(33), p<.001 (two-tailed). This finding suggests that the higher-order thinking skills of the middle-ability students in this intervention were developed as a result of completing the GIS-based intervention.

Following this test, a further between-sample t-test was undertaken to examine whether there was any significant difference in the improvement of higher-order thinking skills between interventions 1 and 3. The results showed that there was a significant difference between the Intervention 1 HOT improvement scores (M=0.333, SD=5.748) and the Intervention 3 HOT improvement scores (M=10.853, SD=4.639); t(65), p<.001 (two-tailed). This finding suggests that, while there is no significant difference in ability level of the two groups upon commencement of the study, there was a significant difference in development of higher-order thinking skills because of the additional level of scaffolding introduced in Intervention 3. This is an important result in the context of this study and suggests that the modification to the GIS-based tasks in this intervention influenced the development of HOT skills of middle-ability students.

In summary, the quantitative results of Intervention 3 showed that the middle-ability students were deemed to be of equal ability and that there was no influence of prior knowledge on the results. As was the case in both Intervention 1 and Intervention 2, neither pedagogical approach (direct instruction or guided discovery) had a stronger influence on student performance in the tests than the other. As was the case with both Intervention 1 and Intervention 2, the results of Intervention 3 also showed that the GIS-based activities had the effect of improving learning outcomes at the lower-order thinking level from pre- to post-test. This improvement suggests that students' lower-order thinking skills were once again engaged, as was the case in the earlier interventions. A key finding of the results of Intervention 3, however, was that the GIS-based learning tasks, implemented in Intervention 3 with the additional forms of scaffolding, did result in improved learning outcomes for the middle-ability students who completed the task. This finding is particularly important, as there was no significant difference in ability between the two groups of students before they commenced Intervention 3; this suggests that the modifications made to the independent variable through the addition of the two forms of hard scaffolding, had an impact as reflected in the improved results. As noted earlier, the GIS-based activities completed by the middle-ability students in Intervention 1 did not engage their higher-order thinking skills and it was suggested that further examination of the reasons for this result needed to be undertaken. This outcome was investigated further, with the result that modifications were made to the GIS-based activities for Intervention 3. It is, therefore, evident that the changes made have resulted in improved learning outcomes at the higher-order thinking level, which is a positive outcome of the study. Further examination of the changes, and their influence, should be undertaken so that the findings can inform further improvements to GIS-based pedagogy and instruction.

4.3.2 Qualitative results

4.3.2.1 Survey and focus group interview results

As noted previously, a change was made to Intervention 3 with the inclusion of more explicit scaffolding to support the students to access each cognitive stage of the activity. This scaffolding occurred via six multimedia screencasts in the direct instruction approach that showed the students how to use the GIS software tools at each stage of the task. The same instructions were given by the teacher using an Interactive Whiteboard (IWB) in the guided discovery approach.

In this intervention, the participants were again willing to share their thoughts about the **lesson features** and these were consistent with the results obtained in Intervention 1 and 2.

It was clear from the comments recorded that the students enjoyed using the GIS. Four students commented on the affordances of using the technology, with statements including “I really enjoyed using the GIS to compare maps and different data sets” and “I want to use GIS more often in my geography classes!!”.

Other comments included “The GIS provided me with an updated source of information that was presented in a way that I could take easily” and “GIS helped me to better understand development by giving accurate information relating to the topic”.

There were again a range of comments relating to the **pedagogical approach.** There was positive support for the group work in the guided discovery task, with two students making comments such as “In groups, it was good as you could think of new ideas and expand on what you are talking about” and “In the group lesson, the teacher let you go by yourself. It wasn’t like do this, do that – you were left to go at your own pace”.

Similarly, there were positive references to the alternative direct instruction approach, consistent with comments from the earlier interventions. The support offered by the teacher was referred to by two students, with statements such as "The teacher was understanding in this lesson [DI] if you got something wrong. He helped you through it". The other noted, "I liked the way that the teacher taught the lesson and the way that the GIS was easy to use and understand".

There was also a strong sense that the increased level of support provided by the additional scaffolding (referred to in the methodology) was of significant benefit. At least six students commented on the value of the videos while completing the learning activity. Some of the comments included "The video definitely made it easier. It was visually appealing and it pointed out the things you needed to do to answer the question". Also: "It was helpful to be able to listen and watch a video that showed us about how to 'Analyse' and 'Explain' questions". Finally, another noted that "We were waiting and reading the question and we were wondering how to answer it. The video helped as it told us how to break it down".

There were also several comments made in support of the teacher delivering the explicit instruction in the guided discovery lesson; however, there were fewer such comments compared to those offered in support of the video screencasts. Examples included "The teacher was obviously more personable than the video but it was good as a general thing to show people what to do" and "The teacher explaining how to use the GIS was better than the video presentation. It was really helpful to understand how to use the tools of the GIS".

When participants referred to their **thinking skills and learning**, their comments were again consistent with those offered in the earlier focus groups. It was clear that the students noted the increasing level of challenge as they completed the activity, noting, "As the lesson progressed, the questions got harder and you needed to respond more thoughtfully".

It was also noted by some students that the questions in each section built on the earlier questions, with statements including "It was clear to see that the questions built up to those types of questions. It was easy to use the information that you had learnt in the earlier tasks to answer those with your own ideas".

There were again several **suggestions for improvement**, including the need for explicit instruction about how to use the GIS; however, there were fewer comments of this nature. What was noted, however, was that several students suggested the explicit instruction could have been delivered before the lesson began. Comments included "The videos ran through the basic things about how to answer certain questions. It would have been better if the video played at the start when you first loaded up the program” and “It would have been good to have had a tutorial before the lesson to learn about the topic. This could have perhaps been done in an online environment”.

One student also made specific reference to the inclusion of open-ended questions, such as those at the end of the lesson, as well as other aspects, suggesting that “It would be good to have more hypothetical questions like those in Part F as well as the use of the Internet and GIS”.

In summary, there were again similarities in the qualitative results to the comments made by students in earlier interventions. To begin with, the students once again enjoyed using the GIS, and this provides further support for the technology as a motivating factor in the classroom. The students commented again on the fact that it was helpful having all the data relevant to the topic together in one place in the program. There was a sense that the information in the GIS was relevant and up to date, and that the GIS helped the students understand the topic they were investigating.

Regarding the pedagogical approaches adopted, students who completed the guided discovery approach again commented on the positive outcomes of working with a partner to discuss new ideas and expand their thoughts. Those who completed the direct instruction approach felt the teacher was very helpful and the level of support offered was very important to them in completing the task. There was also specific reference to both forms of additional scaffolding and explicit instruction – the multimedia screencasts in the direct instruction approach and the guided support offered by the teacher in the guided discovery approach. It was clear that the videos helped the students to know what they were required to do using specific tools within the GIS and that the instructions helped them to understand the key cognitive function at each level (for example, Analyse). There were similar comments in support of the teacher’s guided instruction and the more personal style of this approach was valued.

Once again, the students also commented on the fact that the questions in the task increased in their level of complexity. Some also noted that to answer the questions in the later sections, it was important to have completed the earlier questions as they built upon the knowledge developed in the earlier sections.

While it was noted that the additional support provided in Intervention 3 was valued, several students again requested further instructions about how to use the GIS. Of interest was the fact that some suggested that the instruction or ‘tutorials’ should be delivered at the start of the lesson. There were also several comments offering positive support for the hypothetical open-ended style questions that were included in the latter sections of the task. Students seemed to enjoy this style of questioning and were challenged by them.

4.3.2.2 Comparison of the qualitative results from the three interventions

There was clearly a difference in the amount of detail offered by students in their comments between Intervention 2 (higher-ability students) and Intervention 3 (middle-ability students). The high-ability students who completed Intervention 2 provided considerably more detail in their comments and these provided a sound basis on which to make changes to the way in which the task was delivered in Intervention 3.

Both sets of students also felt positive about using the GIS, and this again provides further support for the technology as one that engages students in the classroom. There were similar comments about the value of having all the data relating to a topic contained within the one program and that it was interactive and easily accessed. Both sets of students did, however, comment on the fact that it would have been good to have had other opportunities to investigate the topic, either independently of the GIS or via research or using embedded Internet links. There were again similarities in the comments from students who requested more embedded multimedia to enhance the information about the topic.

Both cohorts were clear in seeking further guidance about how to use the GIS, despite the additional level of support provided in Intervention 3. The students noted that they felt further scaffolding was warranted and this was provided in response to the feedback in their comments.

The students who completed interventions 1 and 3 were of approximate equal middle ability. Most of the comments provided by both cohorts were similar in their level of detail. Both groups noted that they were genuinely engaged by the GIS and that they enjoyed using the technology. The two groups also commented positively on both pedagogical approaches and it was not possible to ascertain whether one approach was favoured over the other – whereas in Intervention 2, it was evident that the high-ability students favoured the direct instruction approach. Comments about the extent of teacher involvement featured strongly in both sets of qualitative results and the level of support provided by the teacher in both approaches was appreciated, as was the case in Intervention 2. What was clear from the recorded comments was that the two groups of students who completed Intervention 1 felt that they would like greater support in the form of instruction about how to use the GIS. This view was in contrast with the students in Intervention 3, whose comments focused predominantly on the increased level of scaffolding support given to them in Intervention 3. The high-ability students were clearly appreciative of the additional support given to them from either the multimedia video screencast or the explicit teaching from the teacher. As noted in the qualitative results section, at least six students specifically supported the videos, while at least two students offered their support to the explicit teaching from the teacher in the guided discovery approach. These views suggest that the implementation of two forms of hard scaffolding in Intervention 3 did have an impact on the GIS-based activity completed by the students, in the form of improved learning outcomes at the higher-order thinking levels. It can also be noted that the multimedia videos were particularly well received by the students who completed the direct instruction approach using this form of hard scaffolding.

4.4 Summary of results

In this study, it was noted that the pedagogy (whether direct instruction or guided discovery) did not make a difference to student performance. The evidence for this outcome was derived primarily from the quantitative tests undertaken to assess Hypothesis 1 (Test 3) and then supported by the results of the qualitative tests.

Students in each of the interventions noted affordances with both approaches and it was only the high-ability students in Intervention 2 who showed a stronger preference for the direct instruction approach over the guided discovery approach.

Regardless of which pedagogy was used, high-ability students were also able to develop both their higher-order and lower-order thinking skills using GIS. Middle-ability students, however, could not significantly improve their higher-order thinking skills without additional scaffolding. In each intervention, the quantitative results showed that the GIS-based activities undertaken by the students during the activity resulted in improved learning outcomes at the lower-order thinking levels. This outcome contrasted with the higher-order thinking results, which varied between each of the interventions. The results for those who completed Intervention 1 showed that their engagement with the GIS-based activities at the higher-order thinking level did not result in improved learning outcomes. High-ability students in Intervention 2, however, did show improved learning outcomes at the higher cognitive thinking levels of the learning task. This result focused attention on the reasons why the middle-ability students did not produce similar outcomes.

The qualitative results from interventions 1 and 2 provided an insight into student thoughts about certain things they felt would help them engage more effectively with the GIS-based learning task. Several key suggestions were made, including the inclusion of multimedia (example pictures and videos) to enhance the knowledge about the topic they were investigating. Also, several students noted their desire to be given more explicit instruction about how to complete the GIS-based tasks more effectively. These suggestions provided an insight into modifications that were needed for Intervention 3 that might support the middle-ability students to engage more effectively with the higher-order thinking tasks. The decision was therefore made to implement two forms of hard scaffolding (multimedia video screencast and explicit teacher modelling) for Intervention 3 to support the students to engage in higher-order thinking learning outcomes.

The quantitative tests undertaken for Intervention 3, along with the qualitative results recorded, clearly indicate that the addition of the hard scaffolding enabled the middle-ability students to significantly improve learning outcomes at the higher-order thinking cognitive levels. It was also clear that this outcome was not determined by whether the students received the multimedia video screencast or the explicit teacher modelling. Also, the improved learning outcomes recorded at the higher-order thinking level were not dependent on the type of pedagogy used, although the qualitative results show that there was more positive support for the screencast, which was used to support the guided discovery approach.

These results have several implications for the future of GIS teaching and GIS-based instruction; these are explored in the Discussion and Conclusion chapter that follows.

Chapter 5: Discussion and Conclusion

5.1 Overview

Geographic Information Systems (GIS) have been identified as an innovative technology with the potential to enhance the quality of geography education. Essentially a database with mapping capabilities, a GIS can collect, store, manage, retrieve, manipulate, analyse and visualise geographic information that is spatially referenced to the Earth's surface (Britz & Webb, 2016). GIS has rapidly progressed from being an isolated industry-based computer software program to a functional technology utilised in a wide variety of settings, including education (Kerski et al., 2013). Since first appearing in classrooms in the early 1990s, GIS has been identified as a "powerful motivator for learning in and out of the classroom" (Akinyemi, 2016, p.21) with several affordances reported in the literature to support this assertion.

GIS has been recognised by the National Research Council (2006) as a learning technology that can reshape learning across the curriculum, particularly when used by "well-trained and imaginative teachers" (Alibrandi & Baker, 2008, p.3) and effective school ICT infrastructure. Several researchers have also shown that GIS can have a positive impact on attitudes towards computers (West, 2003), understanding of science content (Kulo & Bodzin, 2013) and geographic knowledge (Patterson et al., 2003; Shin, 2007).

Other studies suggest that GIS can improve spatial thinking skills (Lee & Bednarz, 2009; Marsh et al., 2007) as well as spatial language and gestures (Kolvoord & Uttal, 2012; Kolvoord, Uttal & Meadow, 2011). These skills are also reportedly enhanced by the use of other geospatial technologies, such as GPS devices (Huynh, 2009; Lee & Bednarz, 2009).

There are also authors who argue that geography education supported by GIS-based instruction has the potential to contribute to deep geographic learning in a manner that is different from traditional geography education (Baker & White, 2003; Favier & van der Schee, 2012). Those who advocate its use argue that it supports student-centred approaches to teaching and learning (Audet & Paris, 1997; Bednarz & Ludwig, 1997; Johansson, 2003; Kerski, 2008; Landenberger et al., 2006). When integrated within a geographic inquiry-based unit of work, it has the potential to empower students to be active learners in a way that promotes students' critical thinking and analytical skills (Alibrandi, 2003; Baker et al., 2012; Bloom & Palmer-Moloney, 2004; Demirci, 2008; Hagevik, 2003; Johansson, 2003; Pang, 2006). It is also suggested that GIS allows students to engage with real-world problems, connect to their own community, and engage with social concepts and processes (Kerski, 2008; Milson & Kerski, 2012).

One of the central arguments for using GIS is that it can foster critical thinking and problem-solving skills among students, especially when linked with other media and fieldwork (National Research Council, 2006; Kolvoord et al., 2011). Furthermore, it is argued that, as an interdisciplinary technology, it can assist in the development of high-order thinking skills in students (National Research Council, 2006; Drennon, 2005; Kulo & Bodzin, 2013). Liu et al. (2010) also reported higher-order learning outcomes in students using GIS.

Despite considerable early promise, GIS's broader application appears to be limited and its potential unrealised within geography classrooms (Bednarz & van der Schee, 2006; Kerski, 2003; Liu & Zhu, 2008; Moore, Haviland, Moore & Tran, 2016; Wheeler et al., 2010). The use of GIS is not widespread and there is ongoing debate about its value within geography education (Bednarz & van der Schee, 2006; Henry & Semple, 2012; Hohnle et al., 2013; Kankaanrinta, 2004; Kerski, 2001, 2003; Kerski et al., 2013; Kinniburgh, 2008; Lam et al., 2009; Lee & Bednarz, 2009; Møller Madsen & Rump, 2012; Sinton, 2009). As a learning technology in geography, it appears unable to generate wider support from educators except among those enthusiastic teachers who are akin to the 'respectable early adopters' or 'lone pioneering teachers' (National Research Council, 2006; Longley et al., 2001).

Studies investigating the value of GIS in education since the early 1990s suggest that there is little known about the benefits and learning outcomes of GIS (Baker, 2002). Baker and Bednarz (2003) have previously noted the lack of well-designed research studies on the effectiveness of GIS in education, and this may be factor in teachers not engaging further with the technology. More recently, Baker and Langran (2016) called for specific research that describes the effectiveness of or best practice in GIS-related technologies in teacher education and identified further gaps in the research in several areas, including:

- connections between GIS technologies and GIS-based thinking;
- learning (about) GIS-related technologies;
- curriculum and student learning through GIS-based technologies; and
- educator's professional development about how to use GIS-based technologies.

Given that it is not possible to state unequivocally that the use of GIS in secondary education has a clear, positive effect on the development of geographical knowledge and understanding (Doering et al., 2008; Goldstein & Alibrandi, 2013; Kerski, 2001; Lam et al., 2009), it is perhaps surprising that there is a lack of research on how geography teachers can most effectively integrate GIS into their classrooms. This clarity is needed if teachers are to feel empowered to use it. Instructional approaches that integrate GIS and support contemporary pedagogy and rationales for learning are therefore needed, and this research makes a contribution to the debate in this regard.

5.2 Study context

This research was undertaken within a middle-school classroom of an independent boys' school in Australia, using a design-based research methodology. Incorporating a mixed methods approach, key components of GIS-based pedagogy were investigated and evaluated via an examination of the impact of GIS-based pedagogies and student ability levels on the development of geography students' higher-order thinking skills. The quantitative method utilised a repeated measure counterbalanced experimental design including pre- and post-test assessments, while open-ended survey questions and focus groups were used to examine qualitative results.

The central research question for this research was: How and to what extent do GIS-based pedagogies enhance students' higher-order thinking skills in secondary geography?

The research also examined the following sub-research questions:

1. To what extent does pedagogical orientation influence learning in GIS contexts?

2. Does ability level influence the development of student thinking skills using GIS?

3. How can students be best supported to develop higher-order thinking skills using GIS?

5.3 Implications of the finding including recommendations

Several key results emerged from the study and these have been aligned to each of the sub-questions above.

5.3.1 Sub-research question 1

Firstly, pedagogy did not emerge as a key factor that influenced learning outcomes within the GIS-based units completed in the interventions. Two pedagogical orientations were adopted in this study – direct instruction and guided discovery – and neither had more of an impact on student performance than the other. The evidence for this finding came primarily from the quantitative tests undertaken in each intervention to assess Hypothesis 1 (Test 3) with supporting evidence from the qualitative data collected.

Hypothesis 1 sought to address the first sub-question by comparing the total amount of improvement that was recorded for each student under direct instruction and guided discovery approaches. Using a paired within-group two-sample t-test, the two-tailed (directional) hypothesis was tested at a one per cent level of significance (**α** = 0.01), applied also in subsequent tests. It was found that there was no significant difference between the means of the improvement for direct instruction (M=4.242, SD=5.075) and guided discovery (M=4.030, SD=4.946); t(32), p=0.881 (two-tailed) in Intervention 1. On this basis, it was determined that neither direct instruction or guided discovery as used in the lessons for Intervention 1 appeared to influence student performance in the tests.

The qualitative results supported this finding. The middle-ability students who completed Intervention 1 were clearly able to note the key differences between each pedagogy and noted affordances with both approaches. In relation to the direct instruction approach, it was observed by the students that they could finish the task relatively quickly because the teacher provided clear instructions about how to undertake it. Students who completed the guided discovery approach highlighted the fact that working with a partner allowed them to share ideas and discuss the issue being investigated. They also indicated that it was helpful to be able to work through problems together and to ask questions about how to answer the GIS-based questions. Thus, students perceived advantages and disadvantages of both pedagogical approaches, with neither direct instruction or guided discovery clearly seen as better than the other.

Intervention 2 was completed by students of high ability and the results of the paired within-group two-sample t-test used to test Hypothesis 1 showed no significant difference recorded between the means of improvement using direct instruction (M=8.675, SD=4.299) and guided discovery (M=8.950, SD=4.883); t(39), p=0.755 (two-tailed). As was the case in Intervention 1, neither pedagogical approach influenced student learning outcomes in Intervention 2.

The students of high ability provided support for both pedagogical orientations, although it was observed that these students appeared to have a preference for the direct instruction approach over the guided discovery approach, as evidenced by several positive comments. The recorded comments of the high-ability students were also more detailed than the middle-ability students who completed Intervention 1. They also clearly recorded their appreciation of being able to work quickly and independently through the tasks. Similarly, they also offered positive support for the guided discovery approach and the less explicit instruction meant that they could share thoughts with their partner and work on ideas about the questions together.

In Intervention 3, which was completed by students of middle ability, the results of the paired within-group two-sample t-test used to test Hypothesis 1 again showed no significant difference between the means of improvement using direct instruction (M=11.588, SD=4.652) and guided discovery (M=11.529, SD=5.769); t(33), p=0.953 (two-tailed). As was the case with the results for interventions 1 and 2, neither pedagogical orientation influenced student performance in Intervention 3.

The qualitative results produced similar findings to those reported for interventions 1 and 2. Those who completed the direct instruction approach found the teacher's clear instructions very helpful and the level of support that they offered allowed them to complete the task effectively. Those students who completed the guided discovery approach were also complimentary about being able to work with a partner to discuss their thoughts and elaborate on their ideas. Specific reference was also made to both forms of additional scaffolding – the multimedia screencasts in the direct instruction approach and the explicit teacher modelling from the teacher in the guided discovery approach. The comments clearly suggested that the videos were helpful in learning to understand how to use specific GIS tools to answer questions at each higher-order cognitive level. It was also evident that the explicit teacher modelling was also valued by the students, albeit to a lesser extent.

In each of the interventions, students noted affordances with both pedagogical approaches and on this basis, it is possible to accept the null hypothesis that "There is no difference in student improvement under direct instruction and guided discovery pedagogical treatments".

These results, to some extent, inform the ongoing debate about the impact of instruction upon learning, particularly with respect to two contemporary arguments discussed in the literature review. As noted, the first relates to the concept that both novices and experts learn most effectively when they are provided with unguided or minimal instruction. They are expected to discover or construct learning themselves (Bruner, 1961; Papert, 1980; Steffe & Gale, 1995). This argument contrasts with those who argue that explicit guided instruction is more beneficial (Cronbach & Snow, 1977; Klahr & Nigam, 2004; Shulman & Keisler, 1966; Sweller, 2003).

The central difference between these two schools of thought was highlighted by Kirschner et al. (2006) who, building upon earlier work by Mayer (2004), argued that constructivist approaches to learning, including those that are inquiry-based, are less effective. The basis of this argument is that constructivist approaches overload a learner's working memory and that this type of learning is short-term and does not enable a student to commit the information to their long-term memory. Kirschner et al. (2006) suggest that students who do not have strong pre-existing knowledge about a topic lack the proper schemas to integrate new information or knowledge. Therefore, cognitive overload can occur (particularly in novice learners) and they can become frustrated by what they are doing. Therefore, it is argued that "decades of research clearly demonstrate that for novices, direct, explicit instruction is more effective and more efficient than partial guidance" (Clark et al., 2012, p.6).

The counter-argument asserts that constructivist approaches can be effective, particularly when there is a conscious attempt made to reduce students' cognitive load using scaffolding (Hmelo-Silver et al., 2007; Kim, 2005; Spiro & DeSchryver, 2009). It is suggested that the introduction of scaffolding can enable students to access more difficult and complex tasks that would not have been accessible without the scaffolding.

Consideration of the two arguments might suggest that the students who completed each of the interventions would find the guided discovery approach more challenging; however, this was generally not the case. In each of the interventions, it was clear that students of both middle and high ability valued both approaches and neither approach had a greater impact on learning outcomes than the other. The only relevant point to note was that the high-ability students who completed Intervention 2 found the direct instruction approach more relevant and enjoyable, which does in part support the argument put forward by Kirschner et al. (2006).

The two pedagogical approaches implemented in this study were developed using clear guidelines from the literature. It was not, however, possible to ascertain whether one approach was more effective than the other. This result supports the notion that there is no single, universal approach to suit all learning situations; instead, an array of teaching strategies may be employed. Students valued the explicit instruction given to them in the direct instruction approach, as well as the fact that this approach enabled them to move through the task more quickly. The key features of the guided discovery approach included the ability to share ideas with a partner, learners not feeling as rushed and time to discuss thoughts more carefully. Clearly the students in this study valued both approaches and, on this basis, any GIS-based instructional approach that draws on these features will have merit in a middle-school setting.

5.3.2 Sub-research question 2

The second key finding of this study was that middle-ability students were unable to develop their higher-order thinking skills, compared with those students of high ability, without the explicit introduction of different forms of multimedia scaffolding. The evidence for this came primarily from the quantitative tests undertaken to assess Hypothesis 2 (Test 4) and Hypothesis 3 (Test 5) with supporting evidence from the qualitative tests. Hypothesis 2 focused on comparing the means of improvement between each student's pre- and post-test lower-order thinking results (Remembering, Understanding and Apply levels) while Hypothesis 3 compared the same at the higher-order thinking levels (Analyse, Evaluate, Create). Both hypotheses were tested using a paired within-group t-test that evaluated the amount of improvement from pre-to post.

In Intervention 1, there was a significant difference between the lower-order thinking pre-test results ($M=28.152$, $SD=5.386$) and the post-test results ($M=36.091$, $SD=4.869$); $t(32)$, $p<.001$ (two-tailed). This difference suggests that the GIS-based activities undertaken at the lower-order thinking level resulted in improved learning outcomes for the middle-ability students who completed the task.

The qualitative results suggested that the middle-ability students engaged with the lower-order thinking questions. While this was the case, it also appears that they were not challenged in the same way by these questions as they were with the higher-order thinking questions, which they found more interesting. Some minor modifications were also made to the worksheets before Intervention 2 commenced.

The same statistical analysis techniques were conducted on the means of improvement between each student's pre- and post-test results at the higher-order thinking level (Analyse, Evaluate, Create) in Intervention 1. There was no significant difference between the higher-order thinking pre-test results ($M=23.394$, $SD=6.031$) and the post-test results ($M=23.727$, $SD=4.817$); $t(32)$, $p=0.741$ (two-tailed). From this, it can be concluded that there was no improvement in the learning outcomes at the higher-order thinking level of the middle-ability students who completed this intervention. This was a critical result, suggesting that further investigation needed to take place to understand why the GIS-based activities did not engage the higher-order thinking skills of middle-ability students.

Also of interest was the fact that despite the middle-ability students recording no evidence of improvement at the higher-order thinking level, their qualitative comments suggest that they did enjoy completing the tasks that were set at this level. It appears that the open-ended nature of the questions, including the hypothetical situations, engaged the students more effectively than the closed questions in the early stages of the task, even though their performance at this level was less effective. There were also several comments from the middle-ability students that seemed to acknowledge that knowledge attained at the lower-order thinking levels was required to answer the questions at the higher-order thinking level. These comments suggest that the GIS-based activities were, to some extent, appropriately constructed as they guided the middle-ability students through the increasingly complex activities.

Following the analysis of the results obtained from Intervention 1, it was determined that the nature and characteristics of the pedagogical instruction delivered in Intervention 1 would need to be carefully reviewed to consider whether there are deficiencies or limitations in the approach preventing the engagement of higher-order thinking skills in middle-ability students.

In Intervention 2, students of high ability were chosen to participate in the study and the same statistical techniques applied. With regard to the students' performance at the lower-order thinking level, the results of the paired within-group two-sample t-test showed there was a significant difference between the pre-test results ($M=35.075$, $SD=4.190$) and post-test results ($M=44.2$, $SD=3.891$); $t(39)$, $p<.001$ (two-tailed). As was the case in Intervention 1, the GIS-based tasks undertaken clearly resulted in improved learning outcomes at the lower-order thinking level. This outcome provided further validation for the GIS-based activities and their effectiveness in engaging students' lower-order thinking skills.

In the qualitative results, the high-ability students who completed the task were open in noting that the GIS-based activities engaged their thinking and this resulted in an improved learning experience. As was the case in Intervention 1, it was evident that generally the high-ability students found the closed questions in Part A, B and C less challenging and engaging.

In contrast to Intervention 1, however, the results of the paired within-group two-sample t-test used to measure attainment at the higher-order thinking levels showed that there was a significant difference between the pre-test results ($M=28.1$, $SD=5.007$) and post-test results ($M=36.6$, $SD=4.081$); $t(39)$, $p<.001$ (two-tailed). This difference suggests that the higher-order thinking skills of the higher-ability students in this intervention were developed after completing the GIS-based intervention; this is an important result in the context of this study and encourages further examination of how higher-order thinking skills of middle-ability students might be improved from pre- to post-test.

The higher-ability students in Intervention 2 also commented on the types of questions that were presented in the activity, with the open-ended questions providing greater challenge. It was clear that many of the students felt the closed questions in the parts relating to remembering, understanding and applying for both topics were less challenging and engaging to them. There was a strong sense in the comments offered by the high-ability students that the knowledge acquired in earlier parts of the module (lower-order thinking questions) enabled them to answer the more difficult scenario-based higher-order thinking questions in the latter sections. These comments were similar to those made by middle-ability students in Intervention 1. Again, the open-ended questions were acknowledged by some students as engaging and generally being more interesting than the closed questions in the lower-order thinking sections.

Students also noted that they could build upon the knowledge acquired in the earlier sections of the activity to complete the tasks at the higher levels. In Intervention 1, the middle-ability students showed interest in the more complex higher-order tasks; however, they were not able to answer them effectively. This was not the case in Intervention 2, with the high-ability students showing improved learning outcomes at the higher-order thinking levels after completing the GIS-based tasks at these levels.

The students who completed Intervention 2 also made several suggestions to include additional forms of instruction that would inform them about how to answer specific questions in the task. Those suggestions included additional multimedia support (both pictures and videos) to enhance their learning experience. A few students recommended the inclusion of additional research opportunities to learn more about the topic before the lesson took place; this is a relevant consideration given the students' experience of the two topics (Development and Energy) prior to the interventions was minimal.

In Intervention 3, changes were made to assist the middle-ability students to improve learning outcomes at the higher-order thinking level with the impact of these changes to be discussed in Section 5.3.3. At the lower-order thinking level, the results of the paired within-group two-sample t-test used to assess the improvement at the lower order thinking level showed a significant difference between the pre-test results (M=29.353, SD=5.057) and post-test results (M=41.618, SD=4.652); t(33), p<.001 (two-tailed). This result again indicated that the GIS-based activities adopted within the intervention had the effect of improving learning outcomes at the lower-order thinking level, as was the case in earlier interventions.

In summarising these results, the middle-ability students who completed interventions 1 and 3 were able to engage their lower-order thinking skills, as were the high-ability students who completed Intervention 2. The results indicate that the GIS-based activities adopted were effective in developing students' lower-order thinking skills and, on this basis, it is possible to accept the alternate Hypothesis 2 that "The GIS-based learning activities will result in a change in students' lower order thinking skills".

5.3.3 Sub-research question 3

In Intervention 3, changes were made to assist the middle-ability students to improve learning outcomes at the higher-order thinking level. These changes occurred in the form of multimedia scaffolding and teacher modelling that enabled the students to engage more effectively with questions developed to engage their higher-order thinking level. These changes were made in response to the determination that middle-ability students were unable to access learning outcomes at the higher-order thinking level as identified by the results in Intervention 1.

The results of the paired within-group two-sample t-test used to test Hypothesis 3, showed that there was a significant difference calculated between the pre-test results (M=19.059, SD=5.222) and post-test results (M=29.912, SD=2.927); t(33), p<.001 (two-tailed). This difference suggests that in this intervention, the GIS-based activities were effective in achieving improved outcomes at the higher-order thinking level.

On this basis, it is possible to also accept the alternate Hypothesis 3 that "The GIS-based learning activities will result in a change in students' higher-order thinking skills", but only after the introduction of additional scaffolding in the learning task to support middle-ability students.

To validate this finding, a further test was undertaken to determine whether there was any significant difference in the improved learning at the higher-order thinking levels between interventions 1 and 3. The between-sample t-test results showed that there was a significant difference between the Intervention 1 HOT improvement scores (M=0.333, SD=5.748) and the Intervention 3 HOT improvement scores (M=10.853, SD=4.639); t(65), p<.001. From this it can be concluded that while there is no significant difference in ability level of the two groups upon commencement of the study, the additional scaffolding introduced in Intervention 3 influenced performance at the higher-order thinking level. This outcome contrasts with previous results produced by middle-ability students in Intervention 1.

These results also indicate that ability does effect learning outcomes in a GIS-based task (see Sub-research question 2); however, carefully constructed instructional frameworks have the potential to address this issue as shown by the research findings stated above.

The qualitative comments from the middle-ability students who completed Intervention 3 predominantly focused on the role of the additional scaffolding given to them to support their thinking. Of the two forms of scaffolding, there appeared to be greater appreciation of the multimedia screencasts than the explicit teacher modelling; however, both forms were valued and deemed to be of benefit in enhancing learning outcomes.

The students also made several observations about the lower-order thinking tasks, but the most relevant point was that they clearly noted the increasing level of complexity of the questions as they worked through the tasks, particularly as the questions moved from the lower-order thinking levels to the higher-order thinking levels.

There is strong support in contemporary educational settings for developing thinking skills in students; however, there is considerable debate about which approaches are more effective in achieving this, particularly with respect to higher-order thinking skills (Barnett & Francis, 2012; Fischer et al., 2011; Wagner et al., 2014). In a contemporary educational setting, teachers must consider various pedagogical approaches or strategies to teach learners in a way that results in effective learning (Moseley et al., 2005).

The current emphasis on the development of thinking skills provides a strong contrast to the focus of previous eras, when the main role of teachers was to transmit information to students using traditional methods aligned with behaviourist theories (Bransford et al., 2000). Learning was once considered linear, with complex understanding only occurring after basic, prerequisite learning was acquired (Zohar et al., 2001). Only those students who had mastered the lower levels were ‘allowed’ to progress to higher cognitive stages and, therefore, less able students were left to engage with lower-order thinking tasks only. This approach contrasts with a more contemporary assumption that students learn most effectively when a school’s curriculum matches its students’ learning abilities. This latter assumption is underpinned by the view that when students understand what is being taught, they are more likely to actively engage in the learning process and less likely to disengage from classroom instruction (Hallinan et al., 2003). There is also a push to incorporate more challenging higher-order thinking tasks; however, most students require encouragement and assistance to engage with these processes (Heong et al., 2011).

Zohar and Dori (2003) argue that higher-order thinking should be applied to all learning and to all learners. Previously, instruction to engage higher-order thinking skills was considered appropriate for only a small portion of the student population, for example those with high ability. It was noted also that low-achieving students are overly challenged, and thus frustrated, by teaching that includes activities focused on higher-order thinking. In their research, Zohar and Dori (2003) note that teachers should encourage students of all academic levels to engage in learning activities that involve higher-order thinking skills. This study supports this assertion. With specific guided support and instruction, students of middle ability could engage with higher-order thinking processes, and this finding will inform broader discussion in this regard, as few empirical studies exist in this area (Marin & Halpern, 2011).

The final and important result of this research was that well-targeted and specifically designed scaffolding (multimedia and teacher modelling) can assist middle-ability students to develop their higher-order thinking skills during GIS-based learning tasks. This result was identified after careful examination of the results in each intervention, particularly the qualitative feedback from the students, as well as a detailed review of the literature.

After careful consideration of the information obtained from the students in interventions 1 and 2, additional forms of scaffolding were implemented at the higher-order thinking level in both pedagogical orientations. This action followed careful examination of previous research and literature relating to scaffolding, and specifically those forms that utilise multimedia, as it was felt that the students were seeking more explicit instruction in this regard. As a result, three multimedia (video) screencasts were developed in the direct instruction approach, with each video showing the students how to use the GIS functions to complete the tasks at the Analyse, Evaluate and Create cognitive level. Similarly, the students who completed the guided discovery approach received similar instructions, delivered not through a multimedia screencast but via explicit teacher modelling.

The rationale for doing so was that the middle-ability students were unable to answer the higher-order thinking questions effectively in Intervention 1. Middle-ability students were not able to show improved learning outcomes at the higher-order thinking level after completing the GIS-based activities. This was a key result and raised several questions about how the learning task and/or instructional framework adopted could be modified to prevent this occurring. It was also noted during this intervention that several middle-ability students showed an interest in receiving clearer and more explicit instructions before and during the lesson, specifically regarding how to use the tools and functions of the GIS. Several students suggested the inclusion of video demonstrations showing them how to use the GIS. Both groups of high-ability students in Intervention 2 made requests for the inclusion of more multimedia to enable them to learn more about the topic, which would enhance their learning experience.

There were specific calls by the higher-ability students who completed Intervention 2 to be provided with more explicit instructional support that showed them how to use the tools and functions of the GIS to answer the questions. As the students in all interventions showed improvement at the lower-order thinking level, it was decided to implement the increased scaffolding at the higher-order thinking levels only.

As noted previously, the results for Intervention 3 showed improved learning outcomes at the higher-order thinking level after the inclusion of additional forms of scaffolding. This outcome is particularly important, as there was no significant difference in ability between the middle-ability students who completed interventions 1 and 3.

Both forms of scaffolding were acknowledged by the students as being helpful and making a difference to their understanding of how to complete each task at the higher-order thinking levels. The students did suggest that they saw more value in the multimedia screencasts than the explicit teacher modelling, with some indicating that they would have appreciated having access to the instructional videos before the lesson, either during the pre-learning phase or at the start of the lesson.

Teacher modelling was also acknowledged, but to a lesser extent. The teacher who delivered each intervention provided well-constructed and cognitively efficient modelling for the students during each intervention. The students clearly acknowledged their appreciation of the support given to them by the teacher in Intervention 3 and it can be concluded that this was an important factor that contributed to the improved learning outcomes.

There was no significant difference reported in the results between the multimedia scaffolding and explicit teacher instruction. From this, it is possible to suggest that the modality of scaffolding adopted was not the primary influence. Instead, it can be argued that the introduction of scaffolding in either form was enough for the students to complete the tasks effectively, resulting in improving learning outcomes and the development of higher-order thinking skills.

This result is supported by the literature on scaffolding to support novice learners (see Hmelo-Silver & Azevedo, 2006; Hmelo-Silver et al., 2007; Sharma & Hannafin, 2007). It is clear that students who do not have extensive knowledge to develop their own investigations require information to be organised for them to enable them to engage with the learning process.

In this study, hard scaffolds – in the form of multimedia screencasts – and more explicit teacher modelling were adopted to enhance the learning experince, and it is evident that the additional support in this situation was beneficial to the students. This need was identified during the course of the study, after the middle-ability students were unable to engage with higher-order thinking tasks during Intervention 1. It was also noted that, when adopting hard scaffolds, the introduction of technology may be advantageous to the learner and enhance the learning experience (see Demetriadis, Papadopoulos, Stamelos & Fischer, 2008; Kim & Hannafin, 2011; Papadopoulos et al., 2009; Raes et al., 2012; Vreman-de Olde & de Jong, 2006). In this study, additional forms of support in the form of multimedia scaffolding and teacher modelling were utilised. When using modelling techniques in the lesson, the teacher was also required to show how the functions worked using technology so in that sense, both scaffolds utilised multimedia. This is an approach well supported in the literature, with multimedia screencasts, for example, proving helpful in demonstrating different ways of problem-solving and enhancing higher-order conceptual learning outcomes (Esgi & Kocadag, 2015; Lloyd & Robertson, 2012; Oud, 2009; Pinder-Grover et al., 2008).

In designing the two forms of hard scaffolds used in Intervention 3, several principles were followed (see Oud, 2009). Firstly, the instructions were simple and the verbal cues to discuss the GIS-based skills were clear for the students to understand. There were no words or unnecessary graphics used in either the multimedia screencast or during the teacher modelling, allowing the students to focus on the most important visual and verbal cues. Following the suggestions of other researchers (Bowles-Terry et al., 2010; Guo et al., 2014; Mestre, 2012; Morris & Chikwa, 2014), the instructions delivered via the screencast and the teacher modelling were short and presented informally (Guo et al., 2014; Small, 2010). Also, there was a narrow focus on the GIS-skills, with no extraneous or unnecessary information (Sutton-Brady et al., 2009).

The purpose of developing the instructions in this way was to reduce the burden the extra scaffolding would place on the students' working memory. By minimising the cognitive load, the student would be able to process the information carefully and learn more effectively. Multimedia-based scaffolds can place increased demands on a learner's short-term memory because large amounts of information in the form of text, graphics, audio and motion must be integrated (Oud, 2009). This demand was an important design consideration for this study and should be considered for future GIS-based pedagogies that incorporate multimedia elements.

Further consideration was given to the ability level of the student. While the students who completed Intervention 3 were deemed to be of high ability, the amount of pre-knowledge that they had of the topics taught during the intervention was considered minimal and, as such, they can be classified as novice learners. In this study, the additional forms of scaffolding were used to show the novice learner how to complete specific tasks using certain GIS tools, so that they could access the appropriate activities at the higher-order thinking level (Oud, 2009; Renkl, 2005).

The improved learning outcomes suggest that the additional support provided was instrumental in helping the students engage their higher-order thinking skills. This result will inform future discussion about the most effective design of GIS-based pedagogies for use in the classroom. Further investigation of the role of the impact of different forms of scaffolding to support GIS-based pedagogy and instruction could also be warranted considering this finding. There appears to be scant evidence in the broader GIS education research community.

5.4 Limitations

While this research was carefully prepared and undertaken, there are, of course, challenges in conducting research in school-based settings.

Firstly, the participants completed each iteration within interventions 1, 2 and 3, over a 2-hour period before the next group completed their iteration. The topics were then reversed as directed by the methodology, but this occurred the next day due to the school placing restrictions on how much time the students were allowed out of scheduled classes on any given day. The short duration of each intervention may, as a result, not have been long enough to enable effects to emerge – a significant consideration as noticeable impacts on learning are more observable over extended periods of time (for example, a semester).

While the length of each intervention was considered acceptable for the purposes of this study, the length did present some challenges for the students, who were aged between 13 and 14 at the time the research was undertaken. Some of the students showed fatigue, and this was more noticeable towards the end of each iteration. Breaks were given to those students who required it, but these were kept to a minimum to reduce the risk of the break disrupting the flow of the activity.

It is also possible that the direct instruction and guided discovery approaches were applied and implemented differently during each intervention – for example, with more rigid direct instruction from the teacher or less structured guided discovery. To minimise the risk of this issue leading to different results, a thorough review of each iteration was undertaken with the teacher after each intervention. The approach was discussed and the videos were referred to so that the teacher could be made aware of key points.

Also, the experimental group used in this study was relatively small, and the participants were all boys from an independent school setting. It is, therefore, openly acknowledged that this group of students is not representative of all students studying geography within a secondary middle-school setting in Australia and the results are not generalisable to the broader population.

There were also several opportunities for the students to engage with other students who completed the alternate task during breaks, which might have threatened the internal validity of the experiment. Students were asked not to actively engage with other participants between iterations, as this might have resulted in some sharing of information.

Due to the nature of the setting in which the study took place, there were significant time constraints and demands on students, meaning only three interventions could be completed within the design-based research approach. Further interventions would most certainly have enabled further enhancements to be made to the GIS-based tasks and would have likely provided further supporting evidence. Some students were also unable to complete both iterations in an intervention, resulting in their results being excluded from the study. This was a disappointment as it reduced the sample size.

Regarding the research instruments, there were concerns raised by the students about the repetitive nature of the instructions in the booklets. While this was remedied to some extent after Intervention 1, further refinements could have been made to the research instruments if the study had been completed over a longer period.

In addition, because the assessment of the pre- and post-test was undertaken by the researcher, it is possible that there was a certain degree of subjectivity. This observation was particularly applicable to the marking of the pre- and post-test booklets in each iteration. To address this concern, a standard marking scheme with achievement standards was followed carefully to ensure that there was consistency in the quality of the marking.

While every attempt was made to ensure the computers used by the students were in good working order, there were some technical issues experienced during each intervention, particularly when the students loaded the datasets onto the map. These issues were unavoidable, although it is argued that their impact was limited.

The focus groups were led by the researcher, and while the same questions were consistently applied to each intervention, there was undoubtedly a level of subjectivity that occurred during each focus group. This subjectivity may have resulted in varying responses and potential exaggeration of findings, but it is felt that this effect was minimal. To address this concern, a clear set of questions was followed to ensure that each focus group proceeded sequentially. The video was reviewed after each focus group by the researcher to identify inconsistencies, which were noted as being minimal. While the students were given the opportunity to review and verify the transcriptions from each focus group discussion, not all students were availed themselves of the opportunity.

There also existed some potential for researcher bias in the way the results were interpreted. To address this, the researcher worked closely with their primary and secondary supervisor – sharing data sets and collaboration on key steps throughout the analysis process – after each intervention to ensure that the results were analysed correctly. Every attempt was made to be critical of the results, and this provided a useful point for discussion on an ongoing basis between the researcher and supervisors. This approach reduced the potential for any bias being perpetuated that would skew the findings and conclusions.

The teacher was also a member of staff at the school, and while this enabled the students to feel comfortable in each iteration, it might have also resulted in students feeling too relaxed and believing that the testing was less rigorous. Also, the teacher was observed to rush some aspects of the task, which had a small impact on the experience of the students who completed the task. A review of each iteration was undertaken with the teacher to ensure there was consistency in each approach.

5.5 Opportunities for subsequent research in the area

Research into GIS-based education has increased since the early 2000s and certain agendas have emerged within studies exploring the utility of the technology. Some promote GIS as a tool to support problem-based learning and inquiry (Johansson, 2003; Kerski, 2008; Landenberger et al., 2006), while others laud its potential to engage students and teachers in their studies of real world geographical issues, and social and scientific concepts and processes (Milson & Kerski, 2012). Some authors have examined how spatial thinking impacts learning (Gersmehl & Gersmehl, 2007; Lee & Bednarz, 2009), geospatial thinking (Bodzin, Qiong, Bressler & Vallera, 2015; Ishikawa, 2013) and the role of spatial thinking in everyday life (Sinton, Bednarz, Gersmehl, Kolvoord & Uttal, 2013). GIS has also gained traction as a tool to help students describe social issues and engage in public discussion relating to policy (Hogrebe & Tate, 2012), and researching such topics as climate change (Kerski et al., 2013).

The research undertaken has partly addressed concerns by several authors who have previously identified a paucity of rigorous empirical research within the GIS education community (Baker and Bednarz, 2003; Baker et al., 2012). While significant progress has been made, the agenda for the future has not yet been set. More recently, there have been calls for researchers to address several areas, including curriculum and student learning outcomes using GIS-related technologies (Baker et al., 2015). It is anticipated that this study will help to redress this issue by contributing further to the debate about the effectiveness of GIS in education.

While the purpose of this research was to investigate how GIS-based pedagogies can enhance geography students' thinking skills, there remains a considerable gap in the literature in this area. Further research examining the effectiveness of GIS-based pedagogies would contribute to the debate and hopefully provide further validation of GIS as a useful tool in geography education. Such validation would assist other instructional designers who have begun to explore certain frameworks – including technology, pedagogy, and content knowledge (TPACK) – in their efforts to support the integration of GIS technologies into classroom settings (Doering, Koseoglu, Scharber, Henrickson & Lanegran, 2014; Hong & Stonier, 2015). In addition, it would be worthwhile exploring other pedagogical approaches in future studies. Further research could explore the nuances of didactic or directed instruction in more detail. Consideration should also be given, however, to broader constructivist styles, including inquiry-based units conducted over an extended period. The same can be said for approaches that include teacher modelling in some form or another. Other areas of further research could include an examination of the impact of different instructional approaches and pedagogies over a longer time frame.

Further research should also consider more diverse student cohorts, given that this study was undertaken within an independent boys' school. It would also be relevant to examine the extent to which GIS education can enhance learning outcomes for students of low abilities, which would provide a valid contrast to this study. Studies of different genders and age groups would also be valid, with significant potential to conduct a longitudinal study in different settings. Such a study would build on the findings of this study and add further breadth to the value of GIS to support geography education in secondary settings for both boys and girls.

The students who participated in this study clearly supported the inclusion of some form of multimedia within the GIS-based task to enhance their knowledge of the topic and suggested this take the form of pictures or videos. Students also identified the potential value of multimedia as a specific form of scaffolding to assist them to understand how to use specific GIS tasks. The results of this study have identified that multimedia can play a key role in supporting the learning outcomes of the students. However, further research is needed to validate these results and explore the potential of this form of scaffolding in enriching GIS-based instruction.

There is most certainly potential for future studies to examine the value of web-based GIS instruction. In the last five years, significant technological developments have enhanced the potential for GIS to be accessible in the geography classroom using an Internet browser. The emergence of cloud-based technologies, and the widespread use of mobile devices that incorporate geospatial tools, has resulted in schools having more ready access to GIS. Traditional barriers, including software logins, installations and operation system requirements, have been removed, and this is considered a 'watershed' moment for the GIS education community (Baker & Langran, 2016). Further research in this area will assist teachers to explore how functional web-based GIS can be in meeting the pedagogical needs of teachers (Bodzin, Fu, Kulo & Peffer, 2014; Trautmann & MaKinster, 2014).

5.6 Concluding remarks

In addition to providing some directions for future research, this study makes a strong contribution to the broader GIS education community. The overarching research question was to investigate 'How and to what extent can GIS-based pedagogies enhance students' higher-order thinking skills in secondary geography?'. The research undertaken has produced three important outcomes in response to this question.

- Firstly, pedagogical orientation was not identified as a factor that influenced learning outcomes within the GIS-based tasks completed as part of the interventions.
- Secondly, middle-ability students were unable to develop their higher-order thinking skills, compared with those students of high ability, without the introduction of explicitly targeted forms of multimedia scaffolding.
- The final and most important result of this research was that well-targeted and constructed scaffolding can assist middle-ability students develop their higher-order thinking skills during GIS-based learning tasks.

The domain of instructional approaches and GIS-based pedagogies is an area in which there is limited research and, as such, this study seeks to provide valid recommendations to support teachers in their endeavours to use the technology. Educators are typically cautious about adopting technologies within their classrooms, so there is a need to ensure that they are well prepared and equipped to do so; GIS is no different in this regard. As an instructional technology used by teachers, GIS has significant potential not only in geography but in other domains, including environmental science, biology and history, to name just a few.

GIS provides a powerful tool to manage geographic information, assisting students to engage in the process of geographic inquiry to investigate key issues, analyse data and present key findings. As a result, students can engage with important information relating to the world around them. The process of investigation using GIS requires students to engage with their learning using different thinking skills, such as analysing and evaluating. Using GIS also helps students develop their computer literacy and skills in researching key topics or issues. These are valuable skills for both school and later careers. There is evidence of its use at all levels of education – junior, secondary and tertiary. GIS is also a technology used by many major organisations within society. As such, skills in using GIS can provide a valid career path for some students.

The future of GIS education is bright. Recent advances in the technology have made it more readily accessible to educators. The most significant of these developments are the shift to a web-based platform, connectivity with real-time sensors and live data, and the ubiquitous nature of mobile devices that incorporate geospatial functions (Baker & Langran, 2016). This shift has resulted in GIS becoming easier to use, with need for robust technology and knowledge of how to use the desktop software. Teachers are now able to focus their attention on the nature of instruction and how GIS can effectively be used to support their student's needs. This shift provides a unique opportunity to focus on GIS pedagogy and instructional characteristics, rather than challenges associated with trying to access or use the technology. Datasets no longer need to be accessed and loaded onto shared network drives, and the analysis tools and the level of expertise required to set up a GIS project are no longer the domain of specialist IT staff, but rather sit more comfortably with the teacher.

The concern now should be to focus on the teacher and their ability to integrate GIS technology into their classroom practice. Recent developments enhance this potential. It is, however, important to provide strong guidelines for teachers, and this process is easier if there is a strong evidence base on how to integrate GIS effectively in their classroom. It is also hoped that these developments and instructional guidelines will address the concerns relating to the lack of uptake of GIS in geography classrooms. While the broader GIS education research community has drawn attention to the need for further research, it is anticipated that this research will initiate further discussion and encourage others to investigate this important area.

Completing this research has been an invaluable learning experience. While the task has highlighted the sometimes tedious and frustrating nature of the research process, it has also been immensely rewarding. The research has provided the opportunity for reflection on an area of personal interest and professional endeavour that has existed since the late 1990s. The research has provided greater clarity of the importance of providing specific and targeted support to students of differing abilities. GIS instruction supported by targeted scaffolding is one such mechanism that has the potential to facilitate improved learning outcomes for geography students. This research has raised awareness of this notion and, on this basis, it is hoped that future GIS-based instructional frameworks will incorporate elements of this research. In addition, it is hoped that others will heed the call to build on this progress. If this occurs, it will be possible to extend the reach of GIS into geography classrooms within secondary middle-school settings.

References

Australian Curriculum, Assessment and Reporting Authority (ACARA) (2013). *General Capabilities in the Australian Curriculum*. Retrieved from http://www.australiancurriculum.edu.au/GeneralCapabilities/Pdf/Overview

Australian Curriculum, Assessment and Reporting Authority (ACARA) (2017). *Geography F-10 Curriculum*. Retrieved from http://v7-5.australiancurriculum.edu.au/humanities-and-social-sciences/geography/rationale

Australian Curriculum, Assessment and Reporting Authority (ACARA) (2017). *Overview: Structure of Geography*. Retrieved from http://www.australiancurriculum.edu.au/seniorsecondary/humanities-and-social-sciences/geography/structure-of-geography

Akinyemi, F. O. (2015). An Assessment of GIS Use for Teaching in Rwandan Secondary Schools. *The Geography Teacher, 12*(1), 27-40. doi:10.1080/19338341.2014.975144

Australian Geography Teachers Association (AGTA). (2018).

Akinyemi, F. O. (2016). Technology use in Rwandan secondary schools: an assessment of teachers' attitudes towards geographic information systems (GIS). *International Research in Geographical and Environmental Education, 25*(1), 20-35.

Alibrandi, M. (2003). *GIS in the classroom: Using geographic information systems in social studies and environmental science*. Portsmouth: NH: Heinemann.

Alibrandi, M. & Baker, T. (2008). A social history of GIS in Education, 1985-2007. In A. Milson & M. Alibrandi (Eds.), *Digital geography: Geospatial technologies in the social studies classroom*. (pp.3-37). Charlotte, NC: Information Age Publishing.

Amiel, T. & Reeves, T. C. (2008). Design-Based Research and Educational Technology: Rethinking Technology and the Research Agenda. *Educational Technology & Society, 11*(4), 29-40.

Anderson, L. W. & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. New York: Longman.

Anderson, T. & Shattuck, J. (2012). Design-Based Research: A Decade of Progress in Education Research? *Educational Researcher, 41*(1), 16-25.

Andrew, S. & Halcomb, E. J. (2009). *Mixed methods research for nursing and the health sciences*. London, England.: Wiley-Blackwell.

Angeli, C. & Valanides, N. (2009). Instructional effects on critical thinking: performance on ill-defined issues. . *Learning and Instruction, 19*, 322-234.

Ari, A. (2011). Finding Acceptance of Bloom's Revised Cognitive Taxonomy on the International Stage and in Turkey. *Educational Sciences: Theory and Practice, 11*(2), 767-772.

Ashman, A. & Conway, R. (1997). *An introduction to cognitive education*. New York, NY: Routledge.

Audet, R. H. & Ludwig, G. S. (2000). *GIS in schools*. Redlands, CA: ESRI Press.

Audet, R. H. & Paris, J. (1997). GIS Implementation Model for Schools: Assessing the Critical Concerns. *Journal of Geography, 96*(6), 293-300. doi:10.1080/00221349708978810

Ausubel, D. P. (1964). Some Psychological and Educational Limitations of Learning by Discovery. *The Arithmetic Teacher, 11*, 290-302.

Ayorekire, J. & Twinomuhangi, R. (2012). Uganda: Educational reform, the rural-urban digital divide, and the prospects for GIS in schools. In A. J. Milson, A. Demirci & J. J. Kerski (Eds.), *International perspectives on teaching and learning with GIS in secondary schools* (pp.283-289). New York: Springer.

Ayres, P. (2015). State-of-the-Art Research into Multimedia Learning: A Commentary on Mayer's Handbook of Multimedia Learning. *Applied Cognitive Psychology, 29*, 631-636.

Azevedo, R., Cromley, J. G. & Seibert, D. (2004). Does adaptive scaffolding facilitate students' ability to regulate their learning with hypermedia? *Contemporary Educational Psychology, 29*(3), 344-370. doi:http://dx.doi.org/10.1016/j.cedpsych.2003.09.002.

Azevedo, R. & Hadwin, A. F. (2005). Scaffolding self-regulated learning and metacognition: Implications for the design of computer-based scaffolds. *Instructional Science, 33*(5/6), 367-565.

Baker, T. R. (2002). *The effects of Geographic Information Systems (GIS) technologies on students' attitudes, self-efficacy, and achievement in middle school science classrooms*. (PhD), The University of Kansas.

Baker, T. R. (2015). WebGIS in Education. In O. Muniz, A. Demirci & J. van der Schee (Eds.), *Geospatial Technologies and Geography Education in a Changing World: Geospatial Practices and Lessons Learned* (pp.105-114). Japan: Springer.

Baker, T. R., Kerski, J. J., Huynh, N. T., Viehrig, K. & Bednarz, S. W. (2012). Call for an Agenda and Center for GIS Education Research. *Review of International Geographical Education Online, 2*(3).

Baker, T. R., Battersby, S., Bednarz, S. W., Bodzin, A. M., Kolvoord, B., Moore, S., . . . Uttal, D. (2015). A Research Agenda for Geospatial Technologies and Learning. *Journal of Geography, 114*(3), 118-130. doi:10.1080/00221341.2014.950684

Baker, T. R. & Bednarz, S. W. (2003). Lessons Learned from Reviewing Research in GIS Education. *Journal of Geography, 102*, 231-233.

Baker, T. R. & Langran, E. (2016). Geospatial technologies in teacher education: A brief overview. *Contemporary Issues in Technology & Teacher Education, 16*(3).

Baker, T. R. & White, S. H. (2003). The Effects of G.I.S. on Students' Attitudes, Self-efficacy, and Achievement in Middle School Science Classrooms. *Journal of Geography, 102*(6), 243-254. doi:10.1080/00221340308978556

Ball, A. L. & Garton, B. L. (2005). Modeling Higher Order Thinking: The Alignment Between Objective, Classroom Discourse and Assessments. *Journal of Agricultural Education, 46*(2), 58-69.

Barak, M. & Shakhman, L. (2008). Fostering higher-order thinking in science class: Teachers' reflections. *Teachers and Teaching, Theory and Practice, 14*(3), 191-208.

Barnett, J. E. & Francis, A. L. (2012). Using higher order thinking questions to foster critical thinking: a classroom study. *Educational Psychology: An International Journal of Experimental Educational Psychology, 32*(2), 201-211.

Bednarz, S. W. (1995). *Researching new standards: GIS and K-12 geography*. Paper presented at the GIS/LIS, Nashville, Tennessee.

Bednarz, S. W. (2000). Connecting GIS and problem based learning. In R. H. Audet (Ed.), *GIS in schools* (pp.89-101). Redlands, CA: ESRI Press.

Bednarz, S. W. (2004). Geographic Information Systems: A tool to support geography and environmental education? *GeoJournal, 60*.

Bednarz, S. W. & Ludwig, G. S. (1997). Ten things higher education needs to know about GIS in primary and secondary education. *Transactions in GIS, 2*(2), 123-133.

Bednarz, S. W. & van der Schee, J. (2006). Europe and the United States: the implementation of geographic information systems in secondary education in two contexts. *Technology, Pedagogy and Education, 15*(2), 191-205.

Bednarz, S. W., Heffron, S. & Huynh, N. T. (2013). *Road Map for 21st Century Geography Education: Geography Education Research (A report from the Geography Education Research Committee of the Road Map for 21st Century Geography Education Project)*. Retrieved from Washington D.C.:

Belland, B. R., Kim, C. & Hannafin, M. (2013). A Framework for Desigining Scaffolds That Improve Motivation and Cognition. *Educational Psychologist, 48*(4), 243-270.

Benner, P., Sutphen, M., Leonard, V. & Day, L. (2010). *Educating Nurses: A Call for Radical Transformation*. . San Francisco, CA: Jossey-Bass.

Betrancourt, M. (2005). The Animation and Interactivity Principles in Multimedia Learning. In R. E. Mayer (Ed.), *Cambridge Handbook of Multimedia Learning* (pp.287-296). Cambridge: Cambridge University Press.

Betty, P. (2009). Assessing homegrown library collections: Using Google Analytics to track use of screencasts and Flash-based learning objects. *Journal of Electronic Resources Librarianship, 21*(1), 75-92.

Beyer, B. (1988). *Developing a thinking skills program*. Boston, United States of America: Allyn and Bacon.

Bhowmik, M., Banerjee, B. & Banerjee, J. (2013). Role of Pedagogy in Effective Teaching. *Basic Research Journal of Education Research and Review, 2*(1), 1-5.

Bigge, M. & Shermis, S. (2004). *Learning theories for teachers (6th ed.)*. Boston, MA: Pearson.

Biilmann, O. (2001). GIS and remote sensing in primary and secondary education: Rationale, strategies and didactics. In D. R. Green (Ed.), *GIS: A sourcebook for schools* (pp.137-144). London: Taylor & Francis.

Blanton, B. B. (1998). The Application of the Cognitive Learning Theory to Instructional Design. *International Journal of Instructional Media, 25*(2), 171-177.

Bloom, B. (1956). *Taxonomy of educational objectives. Handbook 1: Cognitive domain*. New York: Longmans, Green & Co.

Bloom, E. & Palmer-Moloney, J. (2004). Meeting the Challenge: Integrating Geographic Technology into Today's Social Studies Classroom. *Meridian*(Winter 2004).

Board of Studies, NewSouth Wales. (2003). Geography NSW Stages 4-5 Syllabus. Retrieved from http://www.teachingheritage.nsw.edu.au/4outcomes/g_features.html

Bodemer, D., Ploetzner, R., Feuerlein, I. & Spada, H. (2004). The active integration of information during learning with dynamic and interactive visualisations. *Learning and Instruction, 14*, 325-341.

Bodzin, A., Fu, Q., Kulo, V. & Peffer, T. (2014). Examining the Effect of Enactment of a Geospatial Curriculum on Students' Geospatial Thinking and Reasoning. *Journal of Science Education and Technology, 23*, 562-574.

Bodzin, A., Qiong, F., Bressler, D. & Vallera, F. (2015). Examining the enactment of Web GIS on students' geospatial thinking and reasoning and tectonics understandings. *Computers in the Schools, 32*(1), 63-81.

Boethel, M. & Dimock, V. K. (2000). *Constructing Knowledge with Technology*. Austin, TX: Southwest Educational Development Laboratory.

Bower, M. (2017). *Design of technology-enhanced learning: integrating research and practice*. (First ed.). Bingley, UK: Emerald Publishing.

Bowles-Terry, M., Hensley, M. K. & Hinchliffe, L. J. (2010). Best practices for online video tutorials in academic libraries: A study of student preferences and understanding. *Communications in Information Literacy, 4*(1), 17-28.

Bransford, J., Brown, A. & Cocking, R. (Eds.). (2000). *How people learn: Brain, mind, experience, and school*. Washington DC: National Research Council, National Academy Press.

Brickell, G. & Herrington, J. (2006). Scaffolding learners in authentic, problem based e-learning environments: The Geography Challenge. *Australian Journal of Educational Technology, 22*(4), 531-547.

Britz, H. W. & Webb, P. (2016). The effect of an intervention using GIS-generated geo-spatial data on the promotion of spatial cognition and spatial perspective taking in grade 11 learners. *South African Geographical Journal, 98*(1), 182-193.

Brown, A. & Green, T. (2006). *The essentials of instructional design: Connecting fundamental principles with process and practice*. Upper Saddle River, New Jersey: Pearson.

Brown, J. S., Collins, A. & Duguid, P. (1989). Situated Cognition and the Culture of Learning. *Educational Researcher, 18*(1), 32-42. doi:10.3102/0013189X018001032

Bruner, J. S. (1961). The act of discovery. *Harvard Educational Review, 31*, 21-32.

Brunstein, A., Betts, S. & Anderson, J. (2009). Practice enables successful learning under minimal guidance. *Journal of Educational Psychology, 101*, 790-802.

Brush, T. A. & Saye, J. W. (2002). A Summary of Research Exploring Hard and Soft Scaffolding for Teachers and Students Using a Multimedia Supported Learning Environment. *The Journal of Interactive Online Learning, 1*(2), 1-12.

Bryant, L. M. P. & Favier, T. T. (2015). Professional Development Focusing on Inquiry-Based Learning Using GIS. In O. M. Solari, A. Demirci & J. van der Schee (Eds.), *Geospatial Technologies and Geography Education in a Changing World: Geospatial Practices and Lessons Learned*. Japan: Springer Japan.

Bryman, A. (2012). *Social Research Methods* (4th ed.). Oxford: Oxford University Press.

Bümen, N. T. (2007). Effects of the Original Versus Revised Bloom's Taxonomy on Lesson Planning Skills: A Turkish Study Among Pre-Service Teachers. *International Review of Education, 53*(4), 439-455.

Burkhardt, G., Monsour, M., Valdez, G., Gunn, C., Dawson, M., Lemke, C., . . . Martin, C. (2003). *enGauge® 21st Century Skills: Literacy in the Digital Age*. Retrieved from http://pict.sdsu.edu/engauge21st.pdf

Burrough, P. A. (1986). *Principles of Geographical Information Systems for Land Resources Assessment*. Oxford: Clarendon Press.

Butcher, K. R. (2006). Learning from text with diagrams: Promoting mental model development and inference generation. *Journal of Educational Psychology, 98*(1), 182-197.

Butcher, K. R. (2014). The Multimedia Principle. In R. E. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning (2nd Ed)* (pp.174-205). United States of America: Cambridge University Press.

Carliner, S. (2002). *Designing E-learning*. Alexandria, VA: ASTD Press.

Carlson, T. (2008). Scaffolding Instruction in a University-level GIS Course. *Journal of Planning Education and Research, 28*, 258-262.

Carpenter, T., Franke, M., Jacobs, V., Fennema, E. & Empson, S. (1998). A longitudinal study of invention and understanding in children's multidigit addition and subtraction. *Journal of Research in Mathematics Education, 29*, 3-20.

Carr, A. & Ly, P. (2009). "More than words": screencasting as a reference tool. *Reference Services Review, 37*(4), 408-420.

Casinader, C. & Casinader, N. (1994). Going Somewhere? "Future Problem Solving" Techniques in Geography. *Geographical Education, 7*(2), 42-46.

Catsambis, S., Mulkey, L. M. & Crain, R. L. (2001). For better or for worse? A nationwide study of the social psychological effects of gender and ability grouping in mathematics. *Social Psychology of Education, 5*(1), 83-115.

Chalmers, L. (2006). GIS in New Zealand schools: Issues and prospects. . *International Research in Geographical and Environmental Education, 15*(3), 268-270.

Chen, C. & Law, V. (2015). Scaffolding individual and collaborative game-based learning in learning performance and intrinsic motivation. *Computers in Human Behavior, in press*. doi:http://dx.doi.org/10.1016/j.chb.2015.03.010

Chen, C. M. & Sun, Y. C. (2012). Assessing the effects of different multimedia materials on emotions and learning performance for visual and verbal style learners. *Computers & Education, 59*(4), 1273-1285.

Chen, Z. & Klahr, D. (1999). All other things being equal: children's acquisition of the control of variables strategy. *Child Development, 70*, 1098-1120.

Christensen, T. K. & Osguthorpe, R. T. (2004). How do instructional-design practitioners make instructional-strategy decisions? *Performance Improvement Quarterly, 17*(3), 45-65.

Clark, R. C. & Lyons, C. (2004). *Graphics for Learning: Proven Guidelines for Planning, Designing and Evaluating Visuals in Training Materials*. San Francisco, CA: Pfeiffer/Wiley.

Clark, R. E., Kirschner, P. A. & Sweller, J. (2012). Putting Students on the Path to Learning: The Case for Fully Guided Instruction. *American Educator*(Spring 2012), 6-11.

Cobb, P. & Confrey, J. (2004). Design Experiments in Educational Research. *Educational Researcher, 32*(1), 9-13.

Cobb, P., Wood, T., Yackel, E., Nicholls, J. & Wheatley, G. (1991). Assessment of a problem-centred second grade mathematics project. *Journal of Research in Mathematics Education, 22*, 3-29.

Collins, A., Brown, J. S. & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp.453-494). Hillsdale, NJ: Erlbaum.

Collins, R. (2007). Grouping Students for Success. *Teacher: The National Education Magazine*, 36-39.

Cook, W. J., Collins, S., Flynn, M. K., Cohen, M. & Budiansky, S. (1994). 25 breakthroughs that are changing the way we live and work (pp.46-60): U.S. News and world Report.

Council, N. R. (2006). *Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum*. Washington, DC: The National Academies Press.

Craig, R. C. (1956). Directed versus Independent Discovery of Established Relations. *Journal of Educational Psychology, 47*(4), 223-234.

Crawford, C. & Brown, E. (2002). *Focusing upon higher order thinking skills: WebQuests and the learner-centered mathematical learning environment*. Retrieved from East Lansing, MI:

Creswell, J. W. (1998). *Qualitative inquiry and research design: Choosing among five traditions*. Thousand Oaks, CA.: SAGE.

Creswell, J. W. (2007). *Qualitative inquiry and research design: choosing among five approaches*. (2nd ed.). Thousand Oaks, CA.: SAGE.

Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches*. Thousand Oaks, CA: SAGE Publications Inc.

Creswell, J. W. (2014). Qualitative Methods: Data analysis and interpretation. In J. W. Creswell (Ed.), *Research design: Qualitative, quantitative and mixed methods approaches* (4th ed., pp.194-201). Thousand Oaks, CA.: SAGE.

Creswell, J. W. (2015). Revisiting Mixed Methods and Advancing Scientific Practices. In S. Nagy Hesse-Biber & R. Burke Johnson (Eds.), *The Oxford Handbook of Multimethod and Mixed Methods Research Inquiry*. Oxford: Oxford University Press.

Creswell, J. W. & Plano Clark, V. L. (2007). *Designing and conducting mixed methods research*. Thousand Oaks, CA: Sage.

Creswell, J. W. & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research* (2nd ed.). Thousand Oaks, CA: Sage.

Creswell, J. W. & Poth, C. N. (2017). *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*. (4th ed.) Thousand Oaks, CA: SAGE Publications Inc.

Cronbach, L. & Snow, R. (1977). *Aptitudes and instructional methods: A handbook for research on interactions*. New York: Irvington.

Cuevas, H. M., Fiore, S. M. & Oser, R. L. (2002). Scaffolding cognitive and meat-cognitive processes in low verbal ability learners: Use of diagrams in computer-based training environments. *Instructional Science, 30*(6), 433-464.

Davis, E. A. & Linn, M. C. (2000). Scaffolding students' knowledge integration: Prompts for reflection in KIE. *International Journal of Science Education, 22*, 819-837.

de Jong, T. & Lazonder, A. W. (2014). The Guided Discovery Learning Principle in Multimedia Learning. In R. E. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning (2nd Ed)* (pp.371-390). United States of America: Cambridge University Press.

de Koning, B. B., Tabbers, H. K., Rikers, R. M. J. P. & Paas, F. (2010). Learning by generating vs. receiving instructional explanations: Two approaches to enhance attention cueing in animations. *Computers & Education, 55*(2), 681-691.

Dean, D. & Kuhn, D. (2007). Direct instruction vs. discovery: The long view. *Science Education, 91*, 384-397.

Demetriadis, S. N., Papadopoulos, P. M., Stamelos, I., G. & Fischer, F. (2008). The effect of scaffolding students' context-generating cognitive activity in technology-enhanced case-based learning. *Computers & Education, 51*, 939-954.

Demirci, A. (2008). Evaluating the Implementation and Effectiveness of GIS-Based Application in Secondary School Geography Lessons. *American Journal of Applied Sciences, 5*(3), 169-178.

Demirci, A. (2011). Using Geographic Information Systems (GIS) at Schools Without a Computer Laboratory. *Journal of Geography, 110*(2), 49-59.

Demirci, A. (2015). The Effectiveness of Geospatial Practices in Education. In O. M. Solari, A. Demirci & J. van der Schee (Eds.), *Geospatial Technologies and Geography Education in a Changing World: Geospatial Practices and Lessons Learned*. Japan: Springer Japan.

Demirci, A., Karaburun, A. & Ünlü, M. (2013). Implementation and effectiveness of GIS-based projects in secondary schools. *Journal of Geography, 112*(5), 214-228.

Dey, E., Burn, H. & Gerdes, D. (2009). Bringing the classroom to the web: Effects of using new technologies to capture and deliver lectures. *Research in Higher Education, 50*, 377-393.

Directory, A. S. (2015). Australian Education System. Retrieved from http://www.australianschoolsdirectory.com.au/educationinformation.php?region=48

Doering, A. (2004). *GIS in education: An examination of pedaogy*. Unpublished doctoral dissertation. University of Minnesota. Minnesota.

Doering, A., Hughes, J. & Huffman, D. (2003). Preservice teachers: Are we thinking with technology? *Journal of Computing in Teacher Education, 35*(3), 342-361.

Doering, A., Koseoglu, S., Scharber, C., Henrickson, J. & Lanegran, D. (2014). Technology integration in K–12 geography education using TPACK as a conceptual model. *Journal of Geography, 113*(6), 223-237.

Doering, A. & Veletsianos, G. (2007a). An Investigation of the Use of Real-Time, Authentic Geospatial Data in the K-12 Classroom. *Journal of Geography, 106*(6), 217-225. doi:10.1080/00221340701845219

Doering, A. & Veletsianos, G. (2007b). Multi-scaffolding Environment: An Analysis of Scaffolding and its Impact on Cognitive Load and Problem-Solving Ability. *Journal of Educational Computing Research, 37*(2), 107-129.

Doering, A., Veletsianos, G. & Scharber, C. (2008). Coming of Age: Research and Pedagogy on Geospatial Technologies within K-12 Social Studies Education *Digital Geography* (pp.213-226). Charlotte, NC: Information Age Publishing, Inc.

Doğru, M. & Kalender, S. (2007). Applying the Subject "Cell" Through Constructivist Approach during Science Lessons and the Teacher's View. *Journal of Environmental and Science Education, 2*(1), 3-13.

Dolan, R. P., Hall, T. E., Banerjee, M., Chun, E. & Strangman, N. (2005). Applying Principles of Universal Design to Test Delivery: The Effect of Computer-based Read-aloud on Test Performance of High School Students With Learning Disabilities. *The Journal of Technology, Learning, and Assessment, 3*(7).

Drennon, C. (2005). Teaching Geographic Information Systems in a Problem-Based Learning Environment. *Journal of Geography in Higher Education, 29*(3), 385-402. doi:10.1080/03098260500290934

Driscoll, M. P. (2005). *Psychology of learning for instruction (3rd ed.)*. Boston, MA: Pearson Education.

Drost, E. (2011). Validity and Reliability in Social Science Research. *Education Research and Perspectives, 38*(1), 105-123.

Dunn, P. K., McDonald, C. & Loch, B. (2015). StatsCasts: screencasts for complementing lectures in statistics classes. *International Journal of Mathematical Education in Science and Technology, 46*(4), 521-532.

Duron, R., Limbach, B. & Waugh, W. (2006). Critical Thinking Framework For Any Discipine. *International Journal of Teaching and Learning in Higher Education, 17*(2), 160-166.

Edwards, C. & Rule, A. (2013). Attitudes of Middle School Students: Learning Online Compared to Face to Face. *Journal of Computers in Mathematics and Science Teaching, 32*(1), 49-66.

Eksteen, S., Pretorius, E. & Breetzke, G. (2012). South Africa: Teaching geography with GIS across diverse technological contexts. In A. J. Milson, A. Demirci & J. J. Kerski (Eds.), *International perspectives on teaching and learning with GIS in secondary schools* (pp.225-232). New York: Springer.

Engelmann, S. (2014). What is Direct Instruction? Retrieved from http://www.nifdi.org/what-is-di/basic-philosophy

Environmental Systems Research Institute (ESRI). (2003). Geographic Inquiry: Thinking Geographically. ESRI Schools and Libraries Program. Retrieved from http://www.esri.com/industries/k-12/education/~/media/Files/Pdfs/industries/k-12/pdfs/geoginquiry.pdf

Environmental Systems Research Institute (ESRI). (2011). Geographic Inquiry Process. Retrieved from http://edcommunity.esri.com/~/media/Files/EdCommunity/Lesson Files/g/Geographic_Inquiry_Process.pdf

Ergood, A., Padron, K. & Rebar, L. (2012). Making library screencast tutorials: Factors and processes. *Internet Reference Services Quarterly, 17*(2), 95-107.

Ertmer, P. A. & Newby, T. J. (2013). Behaviorism, Cognitivism, Constructivism: Comparing Critical Features From an Instructional Design Perspective. *Performance Improvement Quarterly, 26*(2), 43-71.

Esgi, N. & Kocadag, T. (2015). Investigation of the Student and Teacher Opinions about the Screencasting Centered Course. *Educational Research International, 4*(2), 14-24.

EUR-Lex. (2011). Key competences for lifelong learning (2006). Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=URISERV:c11090

Evans, D. (2011). Using embryology screencasts: A useful addition to the student learning experience? *Anatomical Sciences Education, 4*(2), 57-63.

Falconer, J., deGrazia, J., Medlin, W. & Holmberg, M. (2009). Using screencasts in ChE courses. *Chemical Engineering Education, 43*(4), 302-305.

Favier, T. T. & van der Schee, J. (2012). Exploring the characteristics of an optimal design for inquiry-based geography education with Geographic Information Systems. *Computers & Education, 58*, 666-677.

Favier, T. T. & van der Schee, J. (2014). The effects of geography lessons with geospatial technologies on the development of high school students' relational thinking. *Computers and Education, 76*, 225-236.

Fay, A. & Mayer, R. E. (1994). Benefits of teaching design skills before teaching LOGO computer programming: evidence for syntax-independent learning. *Journal of Educational Computing Research, 11*, 187-210.

Felouzisa, G. & Charmillota, S. (2013). School tracking and educational inequality: a comparison of 12 education systems in Switzerland. *Comparative Education, 49*(2), 181-205.

Finger, G., Russell, G., Jamieson-Proctor, R. & Russell, N. (2006). *Transforming Learning with ICT: Making IT Happen*. Australia: Pearson.

Fiore, S. M., Cuevas, H. M. & Oser, R. L. (2003). A picture is worth a thousand connections: The facilitative effects of diagrams on mental development and task performance. *Computers in Human Behavior, 19*(2), 185-199.

Fischer, C., Bol, L. & Pribesh, S. (2011). An investigation of higher-order thinking skills in smaller learning community social studies classrooms. *American Secondary Education Journal, 39*(2), 5-26.

Fitzgerald, G. E. & Koury, K. A. (1996). Empirical Advances in Technology-Assisted Instruction for Students with Mild and Moderate Disabilities. *Journal of Research on Computing in Education, 28*(4), 526-553.

Gagne, R. M. (1974). *The conditions of learning* (2nd Edition ed.). New York: Holt, Rinehart & Winston.

Gagne, R. M. (1985). *The Conditions of Learning and Theory of Instruction*. . New York: Holt, Rinehart & Winston.

Gagné, R. M. (1980). Learnable aspects of problem solving. . *Educational Psychologist, 15*(2), 84-92.

Gagne, R. M. & Brown, L. T. (1961). Some factors in the programming of conceptual learning. *Journal of Experimental Psychology, 62*, 313-321.

Gagne, R. M., Wager, W., Golas, K. & Keller, J. (2005). *Principles of instructional design*. Belmont, CA: Wadsworth.

Gallagher, C., Hipkins, R. & Zohar, A. (2012). Positioning thinking within national curriculum and assessment systems: Perspectives from Israel, New Zealand and Northern Ireland. *Thinking Skills and Creativity, 7*, 134-143.

Gamoran, A. (2011). Designing Instruction and Grouping Students to Enhance the Learning of All: New Hope or False Promise? In M. T. Hallinan (Ed.), *Frontiers in Sociology of Education: Frontiers in Sociology and Social Research*: Springer Science+Business Media B.V.

Gamoran, A. & Weinstein, M. (1998). Differentiation and Opportunity in Restructured Schools. *American Journal of Education*, 385-415.

Gardner, J. & Jeon, T. (2010). Creating task-centered instruction for web-based instruction: Obstacles and solution. *Journal of Educational Technology Systems, 38*(1), 21-34.

Geier, R., Blumenfeld, P. C., Marx, R. W., Krajcik, J. S., Fishman, B., Soloway, E. & Clay-Chambers, J. (2008). Standardized Test Outcomes for Students Engaged in Inquiry-Based Science Curricula in the Context of Urban Reform. *Journal of Research in Science Teaching, 45*(8), 922-939.

Gelo, O., Braakmann, D. & Benetka, G. (2008). Quantitative and qualitative research: Beyond the debate. *integrative Psychological and Behavioral Science, 42*(266-290).

Geographic Information Technology & Training Alliance (GITTA). (2010). *GIS tasks: Answering questions*. Retrieved from http://www.gitta.info/what_gis/en/html/overview_answers.html

Gersmehl, P. J. & Gersmehl, C. A. (2007). Spatial Thinking by Young Children: Neurologic Evidence for Early Development and "Educability". *Journal of Geography, 106*(5), 181-191. doi:10.1080/00221340701809108

Glasgow, M. E. S., Dunphy, L. E. & Mainous, R. O. (2010). Innovative nursing educational curriculum for the 21st century. *Nursing Education Perspectives, 31*(6), 355-357.

Glogowska, M. (2011). Paradigms, pragmatism and possibilities: Mixed-methods research in speech and language therapy. *International Journal of Language & Communication Disorders., 46*, 251-260.

Golan, R., Kyza, E. A., Reiser, B. J. & Edelson, D. C. (2002). *Scaffolding the task of analyzing animal behavior with the Animal Landlord software*. Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA.

Goldstein, D. & Alibrandi, M. (2013). Integrating GIS in the Middle School Curriculum: Impacts on Diverse Students' Standardized Test Scores. *Journal of Geography, 112*(2), 68-74. doi:10.1080/00221341.2012.692703

Goodchild, M. & Kemp, K. K. (1990). The NCGIA Core Curriculum in GIS. Santa Barbara, California: Naitonal Center for Geographic Information and Analysis.

Gothos. (2012). American Factfinder Tutorial & Census Geography Updates.

Gould, J. (2002). *Concise Handbook of Experimental Methods for the Behavioral and Biological Sciences*. United States of America: CRC Press LLC.

Green, D. R. (2001). GIS in school education: You don't necessarily need a microcomputer. In D. R. Green (Ed.), *GIS: A Sourcebook for Schools* (pp.34-61). London: Taylor & Francis.

Green, K. R., Pinder-Grover, T. & Millunchick, J. M. (2012). Impact of Screencast Technology: Connecting the Perception of Usefulness and the Reality of Performance. *Journal of Engineering Education, 101*(4), 717-737.

Gryl, I. & Jekel, T. (2012). Re-centering geoinformation in secondary education: Toward a spatial citizenship approach. *Cartographica, 47*(1), 18-28.

Guo, P. J., Kim, J. S. & Rubin, R. (2014). *How video production affects student engagement: an empirical study of MOOC videos*. Paper presented at the First ACM Conference on Learning @ Scale Conference, Atlanta, Georgia, USA.

Guthrie, E. R. (1935). *The psychology of learning*. New York: Harper & Row.

Guthrie, E. R. (1942). Conditioning: A theory of learning in terms of stimulus, response, and association. *The psychology of learning* (Vol. 41st year book of the National Society for the Study of Education, Part II). Chicago: University of Chicago Press.

Guthrie, J. T., McRae, A., Coddington, C. S., Klauda, S. L., Wigfield, A. & Barbosa, P. (2004). Increasing reading comprehension and engagement through concept-oriented reading instruction. *Journal of Educational Psychology, 96*, 403-423.

Hagevik, R. (2003). *The effects of online science instruction using geographic information systems to foster inquiry learning of teachers and middle school science students*. (PhD), North Carolina State University, Raleigh.

Hagevik, R. A. (2011). Fostering 21st century learning with geospatial technologies. Middle grades students learn content through GPS adventures. *Middle School Journal, 43*(1), 15-23.

Hallinan, M. T., Bottoms, E., Pallas, A. M. & Palla, A. M. (2003). Ability Grouping and Students Learning. *Brooking Papers on Education Policy, 6*, 95-140.

Hanna, W. (2007). The New Bloom's Taxonomy: Implications for Music Education. *Arts Education Policy Review, 108*(4).

Hannafin, M., Land, S. & Oliver, K. (1999). Open learning environments: Foundations, methods, and models. In C. M. Reigeluth (Ed.), *Instructional Design Theories and Models (Vol. II)* (pp.115-140). Mahway, NJ: Erlbaum.

Hanson, W. E., Creswell, J. W., Plano Clark, V. L., Petska, K. S. & Creswell, J. D. (2005). *Mixed Methods Research Designs in Counseling Psychology*. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.468.7370&rep=rep1&type=pdf

Harpp, D., Fenster, A., Schwarcz, J., Zorychta, J., Goodyer, E., Hsiao, N. & Parente, J. (2004). Lecture retrieval via the web: Better than being there? *Journal of Chemical Education, 81*(5), 688-690.

Hartsell, T. & Yuen, S. (2006). Video streaming in online learning. *AACE Journal, 14*(1), 31-43.

Harwell, M. R. (2011). Research Design in Qualitative/Quantitative/Mixed Methods. In C. F. Conrad & R. Serlin, C. (Eds.), *The SAGE Handbook for Research in Education: Pursuing Ideas as the Keystone of Exemplary Inquiry* (pp.147-163). Thousand Oaks, CA: SAGE Publications, Inc.

Hattie, J. (2009). *Visible Learning; a synthesis of over 800 meta-analyses relating to achievement* London: Routledge.

Hegarty, M., Canham, M. S. & Fabrikant, S. I. (2010). Thinking about the weather: How display salience and knowledge affect performance in a graphic inference task. *Journal of Experimental Psychology: Learning, Memory & Cognition, 36*(1), 37-53.

Heilesen, S. (2010). What is the academic efficacy of podcasting? *Computers & Education, 55*, 1063-1068.

Henry, P. & Semple, H. (2012). Integrating Online GIS into the K-12 Curricula: Lessons from the Development of a Collaborative GIS in Michigan. *Journal of Geography, 111*(1), 3-14.

Heong, Y. M., Othman, W. B., Yunos, J. B. M., Kiong, T. T., Hassan, R. B. & Mohamad, M. M. B. (2011). The Level of Marzano Higher Order Thinking Skills among Technical Education Students. *International Journal of Social Science and Humanity, 1*(2), 121-125.

Hess, A. N. (2013). The MAGIC of web tutorials: How one library (re)focused its delivery of online learning objects on users. *Journal of Library & Information Services in Distance Learning, 7*(4), 331-348.

Hicks, D. (2007). Lessons for the Future: A Geographical Contribution. *Geography, 92*(3), 179-188.

Hiebert, J. & Wearne, D. (1996). Instruction, understanding, and skill in multidigit addition and subtraction. *Cognition and Instruction, 14*, 251-283.

Hmelo, C. E. & Guzdial, M. (1996). Of black and glass boxes: Scaffolding for learning and doing. In D. C. Edelson & E. A. Domeshek (Eds.), *Proceedings of ICLS 96* (pp.128-134). Charlottesville, VA: AACE.

Hmelo-Silver, C. E. (2006). Design principles for scaffolding technology-based inquiry. In A. M. O'Donnell, C. E. Hmelo-Silver & G. Erkens (Eds.), *Collaborative reasoning, learning and technology* (pp.147-170). Mahway, NJ: Erlbaum.

Hmelo-Silver, C. E. & Azevedo, R. (2006). Understanding complex systems: Some core challenges. *Journal of the Learning Sciences, 15*(1), 53-61.

Hmelo-Silver, C. E., Duncan, R. G. & Chinn, C. A. (2007). Scaffolding and Achievement in Problem-Based and Inquiry Learning: A Response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist, 42*(2), 99-107. doi:10.1080/00461520701263368

Hoffler, T. N. & Leutner, D. (2007). Instructional animation versus static pictures: A meta-analysis. *Learning and Instruction, 17*(6), 722-738.

Hogan, K. (1997). Introduction. In K. Hogan & M. Pressley (Eds.), *Scaffolding student learning* (pp.1-6). Cambridge, MA: Brookline Books.

Hogrebe, M. C. & Tate IV, W. F. (2012). Geospatial Perspective: Toward a Visual Political Literacy Project in Education, Health, and Human Services. *Review of Research in Education, 36*, 67-94. doi:10.3102/0091732X11422861

Hohnle, S., Schubert, J. C. & Uphues, R. (2013). What are the constraints to GIS usage? Selected results of a teacher survey about constraints in the school context. *International Research in Geographical and Environmental Education, 22*(3), 226-240. doi:10.1080/10382046.2013.817662

Hong, J. E. & Stonier, F. (2015). GIS in-service teacher training based on TPACK. *Journal of Geography, 114*(3), 108-117.

Houtsonen, L. (2006). GIS in the School Curriculum: Pedagogical Viewpoints. In T. Johansson (Ed.), *Geographical Information Systems Applications for Schools – GISAS* (pp.23-29). Helsinki: Helsingin Yliopiston Maantieteen Laitoksen Julkaisuja Publicationes Instituti Geographici Universitatis Helsingiensis A141.

Hull, C. L. (1943). *Principles of Behavior: An Introduction to Behavior Theory*. New York: Appleton-Century-Crofts.

Hull, C. L. (1951). *Essentials of Behavior*. New Haven, CT: Yale University Press.

Hull, C. L. (1952). *A Behavior System: An Introduction to Behavior Theory Concerning the Individual Organism*. New Haven: Yale University Press.

Huxhold, W. (1991). *An introduction to urban geographic information systems*. Oxford: Oxford University Press.

Huynh, N. T. (2009). *The Role of Geospatial Thinking and Geographic Skills in Effective Problem Solving with GIS: K-16 Education*. (Doctor of Philosophy), Wilfrid Laurier University. (Paper 1078)

Illeris, K. (2009). *Contemporary Theories of Learning*. Abingdon, Oxon: Routledge: Taylor & Francis Group.

Institute of Australian Geographers (IAG) & the Australian Geography Teacher's Association (AGTA). (2006). *Submission to the Minister for Education, Science and Training on the place of Geography in Australian Schools*. Retrieved from http://studylib.net/doc/9070913/submission---institute-of-australian-geographers

Ishikawa, T. (2013). Geospatial thinking and spatial ability: An empirical examination of knowledge and reasoning in geographical science. *The Professional Geographer, 65*(4), 636-646.

Jenner, P. (2006). Engaging students through the use of GIS at Pimlico State High School. *International Research in Geographical and Environmental Education, 15*(3), 278-282.

Johansson, T. (2003). *GIS in Teacher Education - Facilitating GIS Applications in Secondary School Geography*. Paper presented at the ScanGIS'2003 - The 9th Scandinavian Research Conference on Geographical Information Science, Espoo, Finland. http://pbgis.palmbeach.k12.fl.us/cms/images/GIS_WEB_PDF/GIS_in_Teacher_Education.pdf

Johansson, T. (2006). *Geographical Information Systems Applications for Schools - GISAS*. Helskinki: Helsingin Yliopiston Maantieteen Laitoksen Julkaisuja Publicationes Instituti Geographici Universitatis Helsingiensis A 141.

Johansson, T. & Kaivola, T. (2004, 13-15 August 2004). *One map fits all - A digital raster map and 'edutaining' GIS activities*. Paper presented at the Symposium of Commission on Geographical Education of International Geographical Union in association with Children and Cartography Commission of International Cartographic Association, University of Strathclyde, Glasgow.

Johnson, D. W. & Johnson, R. T. (2004). Cooperation and the use of technology. In D. Jonassen (Ed.), *The handbook of research for educational communications and technology* (pp.785-811). Mahwaj, NJ: Lawrence Erlbaum Associates.

Johnson, R. B. & Onwuegbuzie, A. J. (2004). Mixed Methods Research: A Research Paradigm Whose Time Has Come. *Educational Researcher, 33*(7), 14-26.

Jonassen, D. (2000). *Computers as Mindtools for schools: engaging critical thinking* (2nd ed.). Columbus, OH: Merrill Prentice Hall.

Jonassen, D. H. (1996). *Computers in the Classroom: Mindtools for Critical Thinking*. Englewood Cliffs, New Jersey: Prentice-Hall, Inc.

Kamii, C. & Dominick, A. (1998). The harmful effects of algorithms in grades 1-4. In L. Morrow & M. Kenney (Eds.), *The Teaching and Learning of Algorithms in School Mathematics* (pp.130-140). Reston, VA: National Council Teach Math.

Kankaanrinta, I. (2004). *Information and communication technologies in GISAS schools*. . Retrieved from Helsinki:

Keiper, T. (1996). *Introducing a geographic information system to an elementary classroom: A case study (National Geography Standards)*. (PhD), University of Missouri, Columbia.

Keiper, T. (1999). GIS for elementary students: An inquiry into a new approach to learning geography. *Journal of Geography, 98*, 47-59.

Kemp, K., Goodchild, M. & Dodson, R. (1992). Teaching GIS in Geography. *The Professional Geographer, 44*(2), 181-191.

Kerski, J. J. (1999). *A Nationwide Analysis of the Implementation of GIS in High School Education*. Paper presented at the ESRI Educational User Conference, San Diego. http://proceedings.esri.com/library/userconf/proc99/proceed/papers/pap202/p202.htm

Kerski, J. J. (2000). *The Implementation and Effectiveness of Geographic Information Systems Technology and Methods in Secondary Education*. University of Colorado.

Kerski, J. J. (2001). A National Assessment of GIS in American High Schools. *International Research in Geographical and Environmental Education, 10*(1), 72-84.

Kerski, J. J. (2003). The Implementation and Effectiveness of Geographic Information Systems Technology and Methods in Secondary Education. *Journal of Geography, 102*, 128-137.

Kerski, J. J. (2008). The role of GIS in Digital Earth education. *International Journal of Digital Earth, 1*(4), 326-346. doi:10.1080/17538940802420879

Kerski, J. J. (2015). Why GIS in Education Matters. Retrieved from http://blogs.esri.com/esri/esri-insider/2015/08/10/why-gis-in-education-matters/

Kerski, J. J., Demirci, A. & Milson, A. J. (2013). The Global Landscape of GIS in Secondary Education. *Journal of Geography, 112*(6), 232-247. doi:10.1080/00221341.2013.801506

Kidman, G. C. & Palmer, G. (2006). GIS: The Technology is There but the Teaching is Yet to Catch Up. *International Research in Geographical and Environmental Education, 15*(3), 289-296.

Kim, J. S. (2005). The Effects of a Constructivist Teaching Approach on Student Academic Achievement, Self-concept, and Learning Strategies. *Asia Pacific Education Review, 6*(1), 7-19.

Kim, M. (2010). The current status of GIS in the classroom and factors to consider for increasing the use of GIS in South Korea. *Journal of the Korean Association of Geographic and Environmental Education and Information Technologies, 18*, 173-184.

Kim, M., Bednarz, R. & Lee, S.-I. (2011). GIS Education for Teachers in South Korea: Who Participates and Why? *Journal of the Korean Geographical Society, 46*(3), 382-395.

Kim, M., Kim, K. & Lee, S. I. (2013). Pedagogical potential of a web-based GIS application for migration data: a preliminary investigation in the context of South Korea. *Journal of Geography, 112*, 97-107.

Kim, M. C. & Hannafin, M. J. (2011). Scaffolding problem solving in technology-enhanced learning environments (TELEs): Bridging research and theory with practice. *Computers & Education, 56*, 403-417.

King, F., Goodson, L. & Rohani, F. (1998). Higher Order Thinking Skills. Retrieved from http://www.cala.fsu.edu/files/higher_order_thinking_skills.pdf

Kinniburgh, J. C. (2008). An investigation of the impediments to using geographical information systems (GIS) to enhance teaching and learning in mandatory stage 5 Geography in New South Wales. *Geographical Education, 21*(20-38).

Kinniburgh, J. C. (2010). A Constructivist Approach to using GIS in the New Zealand Classroom. *New Zealand Geographer, 66*, 74-84.

Kirschner, P. A., Sweller, J. & Clark, R. E. (2006). Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching. *Educational Psychologist, 41*(2), 75-86.

Klahr, D. & Nigam, M. (2004). The Equivalence of Learning Paths in Early Science Instruction. *Psychological Science, 15*(10), 661-667.

Kodish, S. & Gittelsohn, J. (2011). Systematic Data Analysis in Qualitative Health Research: Building Credible and Clear Findings. *Sight and Life, 25*(2), 52-56. Retrieved from http://www.sightandlife.org/fileadmin/data/Magazine/2011/25_2_2011/systematic_data_analysis_in_qualitative_health_research.pdf

Koedinger, K. R. & Aleven, V. (2007). Exploring the assistance of dilemma in experiments with cognitive tutors. *Educational Psychology Review, 19*, 239-264.

Kollar, I. & Fischer, F. (2006). Supporting self-regulated learners for a while and what computers can contribute. *Journal of Educational Computing Research, 35*(4), 425-435.

Kolvoord, B. & Uttal, D. (2012). *Does GIS impact students' spatial thinking skills?* Paper presented at the ESRI Education International User Conference, San Diego, CA.

Kolvoord, B., Uttal, D. & Meadow, N. G. (2011). *Using video case studies to assess the impact of the use of GIS on secondary students' spatial thinking skills*. Paper presented at the Spatial Thinking and Geographic Information Sciences, University of Tokyo, Japan.

Kosslyn, S. M. (2007). *Clear and to the Point: 8 Psychological Principles for Compelling PowerPoint Presentations*. New York, NY: Oxford University Press.

Krajcik, J., Blumenfeld, P. C., Marx, R. W., Bass, K. M., Fredricks, J. & Soloway, E. (1998). Inquiry in project-based science classroom: Initial attempts by middle school students. *Journal of the Learning Sciences, 7*, 313-350.

Krajcik, J., McNeill, K. L. & Reiser, B. J. (2008). Learning-goals-driven design model: Developing curriculum materials that align with national standards and incorporate project-based pedagogy. *Science Education, 92*, 1-32.

Krathwohl, D. R. (2002). A Revision of Bloom's Taxonomy: An Overview. *Theory into Practice, 41*(4), 212-218.

Kriewaldt, J. (2006). The Key Role of Metacognition in an Inquiry-Based Geography Curriculum. *Geographical Education, 19*, 24-30.

Kuchinke, P. K. (1999). Philosophical Foundations of Human Resource Development *Annual Meeting of the Association for Career and Technical Education*. Orlando, FL: AECT.

Kuklthau, C. C., Maniotes, L. K. & Caspari, A. K. (2007). *Guided inquiry: Learning in the 21st century*. (L. Unlimited Ed.). Westport, CT & London.

Kulo, V. & Bodzin, A. (2013). The Impact of a Geospatial Technology-Supported Energy Curriculum on Middle School Students' Science Achievement. *Journal of Science Education and Technology, 22*, 25-36. doi:10.1007/s10956-012-9373-0

Lajoie, S. P. (2005). Extending the scaffolding metaphor. *Instructional Science, 33*(5/6), 541-557.

Lajoie, S. P. (2014). Multimedia Learning of Cognitive Processes. In R. E. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning (2nd Ed)* (pp.623-646). United States of America: Cambridge University Press.

Lam, C.-C., Lai, E. & Wong, J. (2009). Implementation of geographic information system (GIS) in secondary geography curriculum in Hong Kong: current situations and future directions. *International Research in Geographical and Environmental Education, 18*(1), 57-74.

Lambert, D. & Balderstone, D. (2000). *Learning to Teach Geography in the Secondary School. A Companion to School Experience*. London, New York: Routledge Falmer.

Landenberger, R. E., Warner, T. A., Ensign, T. I. & Nellis, M. D. (2006). Using Remote Sensing and GIS to Teach Inquiry-Based Spatial Thinking Skills: An Example Using the GLOBE Program's Integrated Earth Systems Science. *Geocarto International, 21*(3), 61-71.

Lateh, H. & Muniandy, V. (2011). Technology integrated teaching in Malaysian schools: GIS, a SWOT analysis. *World Journal on Educational Technology, 3*(2), 64-74.

Lay, J.-G., Chi, Y.-L., Hsieh, Y.-S. & Chen, Y.-W. (2013). What influences geography teachers' usage of geographic information systems? A structural equation analysis. *Computers & Education, 62*, 191-195.

Lee, H., Plass, J. L. & Homer, B. D. (2006). Optimizing Cognitive Load for Learning From Computer-Based Science Simulations. *Journal of Educational Psychology, 98*(4), 902-913.

Lee, H. S. & Anderson, J. R. (2013). Student Learning: What Has Instruction Got do Do With It? *The Annual Review of Psychology*, 445-469.

Lee, J. w. & Bednarz, R. (2009). Effect of GIS Learning on Spatial Thinking. *Journal of Geography in Higher Education, 33*(2), 183-198. doi:10.1080/03098260802276714

Lee, M., Pradham, S. & Dangarno, B. (2008). The effectiveness of screencasts and cognitive tools as scaffolding for novice object-oriented programmers. *Journal of Information Technology Education, 7*, 61-80.

Lemberg, D. & Stoltman, J. P. (2001). Geography teaching and the new technologies: Opportunities and challenges. *Journal of Education, 181*(3), 63-76.

Liu, S. & Zhu, X. (2008). Designing a Structured and Interactive Learning Environment Based on GIS for Secondary Geography Education. *Journal of Geography, 107*(1), 12-19. doi:10.1080/00221340801944425

Liu, Y., Bui, E., Chang, C.-H. & Lossman, H. G. (2010). PBL-GIS in Secondary Geography Education: Does It Result in Higher-Order Learning Outcomes? *Journal of Geography, 109*(4), 150-158.

Lloyd, S. A. & Robertson, C. L. (2012). Screencast tutorials enhance student learning of statistics. *Teaching of Psychology, 39*(1), 67-71.

Lloyd, W. J. (2001). Integrating GIS into the Undergraduate Learning Environment. *Journal of Geography, 100*(5), 158-163. doi:10.1080/00221340108978443

Loch, B., Jordan, C. R., Lowe, T. W. & Mestel, B. D. (2013). Do screencasts help to revise prerequisite mathematics? An investigation of student performance and perception. *International Journal of Mathematical Education in Science and Technology, 45*(2), 256-268.

Loch, B. & McLoughlin, C. (2011). *An instructional design model for screencasting: Engaging students in self-regulated learning*. Paper presented at the ascilite 2011 - Changing Demands, Changing Directions, Wrest Point, Hobart, Tasmania, Australia.

Long, H. (2017). Validity in mixed methods research in education: the application of Habermas' critical theory. *International Journal Of Research & Method In Education, 40*(2), 201-213.

Longley, P., Goodchild, M., Maguire, D. & Rhind, D. (2001). *Geographic Information Systems and Science* (P. Longley, M. Goodchild, D. Maguire & D. Rhind Eds.): Wiley.

Lucas, S. (2002). AIL 601: Principles of Instructional Technology, Theories/Models of Learning: Instructivism. Retrieved from http://susanlucas.com/it/ail601/instructivism.html

Lynch, S., Kuipers, J., Pyke, C. & Szesze, M. (2005). Examining the effects of a highly rated science curriculum unit on diverse students: Results from a planning grant. *Journal of Research in Science Teaching, 42*, 921-946.

Maccini, P., Gagnon, J. C. & Hughes, C. A. (2002). Technology-Based Practices for Secondary Students with Learning Disabilities. *Learning Disability Quarterly, 25*(4), 247-261.

Malibar, I. & Pountney, D. (2002). *Using technology to integrate constructivism and visualisation in mathematics education*. Paper presented at the 2nd International Conference on the Teaching of Mathematics, Hersonissos, Crete, Greece.

Mantei, J. (2008, 18-21 June 2008). *Using a design based research approach to explore the ways that primary school teachers conceptualise authentic learning: A work in progress*. Paper presented at the Emerging Technologies Conference, University of Wollongong.

Marin, L. M. & Halpern, D. F. (2011). Pedagogy for developing critical thinking in adolescents: Explicit instruction produces greatest gains. *Thinking Skills and Creativity, 6*, 1-13.

Marsh, M., Golledge, R. & Battersby, S. E. (2007). Geospatial Concept Understanding and Recognition in G6–College Students: A Preliminary Argument for Minimal GIS. *Annals of the Association of American Geographers, 97*(4), 696-712.

Marshall, J. C. & Horton, R. M. (2011). The Relationship of Teacher-Facilitated, Inquiry-Based Instruction to Student Higher-Order Thinking. *School Science & Mathematics, 111*(3), 93-101.

Marzano, R. J. (2003). *What works in Schools: Translating Research into Action*. Alexandria, VA: Association for Supervision and Curriculum Development.

Marzano, R. J. & Kendall, J. S. (2007). *The New Taxonomy of Educational Objectives* (Second Edition ed.). Thousand Oaks, California: Corwin Press, A Sage Publications Company.

Matlen, B. & Klahr, D. (2010). Sequential effects of high and low guidance on children's early science learning. In K. Gomez, L. Lyons & J. Radinsky (Eds.), *Proceedings of the 9th International Conference of the Learning Sciences* (pp.1016-1023): International Society of the Learning Sciences.

Maudsley, G. (2011). Mixing it but not mixed-up: Mixed methods research in medical education (a critical narrative review). *Medical Teacher, 33*, e92-e104.

Maxcy, S. J. (2003). Pragmatic threads in mixed methods research in the social sciences: The search for multiple modes of inquiry and the end of the philosophy of formalism. In A. Tashakkori & C. Teddlie (Eds.), *Handbook of mixed methods in social and behavioural research*. (pp.51-89). Thousand Oaks, CA.: Sage.

Mayer, R. E. (1989). Systematic thinking fostered by illustrations in scientific text. *Journal of Educational Psychology, 81*(2), 240-246.

Mayer, R. E. (2003). The promise of multimedia learning: using the same instructional design methods across different media. *Learning and Instruction, 13*, 125-139.

Mayer, R. E. (2004). Should there be a three-strikes rule against pure discovery learning? The case for guided methods of instruction. *Am Psychol, 59*(1), 14-19. doi:10.1037/0003-066X.59.1.14

Mayer, R. E. (2006). Ten research-based principles of multmedia learning. In H. F. O'Neil & R. S. Perez (Eds.), *Web-based Learning: Theory, Research, and Practice* (pp.371-390). Mahwah, NJ: Lawrence Erlbaum Associates.

Mayer, R. E. (2009). *Multimedia learning (2nd Ed)*. New York: Cambridge University Press.

Mayer, R. E. (2014a). *The Cambridge Handbook of Multimedia Learning (2nd Ed)* (R. E. Mayer Ed.). United States of America: Cambridge University Press.

Mayer, R. E. (2014b). Incorporating motivation into multimedia learning. *Learning and Instruction, 29*, 171-173.

Mayer, R. E. (2014c). Introduction to multimedia learning. In R. E. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning (2nd Ed)* (pp.1-24). United States of America: Cambridge University Press.

Mayer, R. E., Bove, W., Bryman, A., Mars, R. & Tapangco, L. (1996). When less is more: Meaningful learning from visual and verbal summaries of science textbook lessons. *Journal of Educational Psychology, 88*(1), 64-73.

Mayer, R. E. & Gallini, J. (1990). When is an illustration worth ten thousand words? *Journal of Educational Psychology, 82*, 715-726.

Mayer, R. E., Heiser, J. & Lonn, S. (2001). Cognitive constraints on multimedia learning: when presenting more material results in less understanding. *Journal of Educational Psychology, 93*(1), 187-198.

McCombs, S. & Liu, Y. (2007). The efficacy of podcasting technology in instructional delivery. . *International Journal of Technology in Teaching and Learning, 3*(2), 123-134.

McLeod, G. (2003). Learning Theory and Instructional Design. *Learning Matters, 2*(Fall 2003), 35-43.

McLeod, S. (2007). Experimental Design. Retrieved from http://www.simplypsychology.org/experimental-designs.html

Meaney, M. (2006). Towards Geographic Information Systems (GIS) implementation: A case study. *International Research in Geographical and Environmental Education, 15*(3), 283-288.

Merriam, S. B. & Caffarella, R. S. (1999). *Learning in Adulthood: A Comprehensive Guide* (2nd Edition ed.). San Francisco: Jossey-Bass.

Merrill, D. M. (2001). Components of Instruction Toward a Theoretical Tool for Instructional Design. *Instructional Science, 29*, 291-310.

Merrill, D. M. (2010). *First Principles of instruction* Lawrence Erlbaum Associates Publishers.

Mestre, L. (2012). *Designing effective library tutorials: a guide for accommodating multiple learning styles*. Oxford, UK: Elsevier.

Meyer, J. W., Butterick, J., Olkin, M. & Zack, G. (1999). GIS in the K-12 Curriculum: A Cautionary Note. *Professional Geographer, 51*(4), 571-578.

Milson, A. J., Demirci, A. & Kerski, J. J. (2013). The World at Their Fingertips: A New Age for Spatial Thinking. In A. J. Milson, A. Demirci & J. J. Kerski (Eds.), *International Perspectives on Teaching and Learning with GIS in Secondary Schools* (pp.1-11). Dordrecht, Heidelberg, London, New York: Springer Science+Business Media B. V. .

Milson, A. J., Demirci, A. & Kerski, J. J. (Eds.). (2012). *International Perspectives on Teaching and Learning with GIS in Secondary Schools*. Dordrecht, Heidelberg, London, New York: Springer Science+Business Media B. V. .

Milson, A. J. & Kerski, J. J. (2012). Around the world with geospatial technologies. . *Social Education, 76*(2), 105-108.

Milson, A. J. & Roberts, J. A. (2008). The Status of Geospatial Technologies in U.S. High School Geography Standards. In A. J. Milson & M. Alibrandi (Eds.), *Digital Geography: Geospatial Technologies in the Social Studies Classroom* (pp.39-59). Charlotte, NC: Information Age Publishing Inc.

Milvain, C. (2008). Thinking Skills within the Humanities Discipline. *Ethos, 16*(4), 6-10.

Ministerial Council on Education, Employment, Training and Youth Affairs (MCEETYA). (2008). *Melbourne Declaration on Educational Goals for Young Australians*. Retrieved from http://www.curriculum.edu.au/verve/_resources/National_Declaration_on_the_Educational_Goals_for_Young_Australians.pdf

Ministry of Education, Singapore. (2014). 21st Century Competencies. Retrieved from http://www.moe.gov.sg/education/21cc/

Molina Azorin, J. & Cameron, R. (2010). The Application of Mixed Methods in Organisational Research: A Literature Review. *The Electronic Journal of Business Methods, 8*(2), 95-105.

Møller Madsen, L. & Rump, C. (2012). Considerations of How to Study Learning Processes when Students use GIS as an Instrument for Developing Spatial Thinking Skills. *Journal of Geography in Higher Education, 36*(1), 97-116.

Moore, S., Haviland, D., Moore, W. & Tran, M. (2016). Preparing Teachers to Use GIS: The Impact of a Hybrid Professional Development Program on Teachers' Use of GIS. *Journal of Science Education and Technology, 25*, 930-946.

Moreno, R., Ozogul, G. & Reisslein, M. (2011). Teaching with concrete and abstract visual representations: Effects on students' problem solving, problem representations, and learning perceptions. *Journal of Educational Psychology, 103*(1), 32-47.

Morgan, A. (2006). Developing geographical wisdom: post-formal thinking about and relating to the world. *International Research in Geographical and Environmental Education, 15*, 336-352.

Morris, C. & Chikwa, G. (2014). Screencasts: How effective are they adn how do students engage with them? *Active Learning in Higher Education, 15*(1), 25-37.

Morris, I. (2012). *The Importance of Well being in Education*. Paper presented at the Inaugral conference of the Jubilee Centre for Character and Values, Character and Public Policy: Educating for an Ethical Life, University of Birmingham. http://www.jubileecentre.ac.uk/userfiles/jubileecentre/pdf/conference-papers/MorrisI-The-importance-of-well-being-in-education.pdf

Moseley, D., Baumfield, V., Elliott, J., Gregson, M., Higgins, S., Miller, J. & Newton, D. (2005). *Frameworks for thinking: A handbook for teaching and learning*. Cambridge: Cambridge University Press.

Murphy, J. S. (2015). *Reflecting the science of instruction? Screencasting in Australian and New Zealand academic libraries: a content analysis*. (Master of Information Studies), Victoria University of Wellington.

Naish, M., Rawling, E. & Hart, C. (1987). *Geography 16-19: The contribution of a curriculum project to 16-19 education*. London: Longman.

Näsström, G. (2009). Interpretation of standards with Bloom's revised taxonomy: a comparison of teachers and assessment experts. *International Journal of Ressearch & Method in Education, 32*(1), 39-51.

National Geography Standards, Geography Education Standards Project. (1994). *Geography for Life: The National Geography Standards*. Washington D.C.: National Geographic Society Committee on Research and Exploration. Retrievedfrom https://archive.org/details/geographyforlife00geog

National Research Council (NRC). (2006). *Learning to Think Spatially*. Washington DC: The National Academies Press.

Neighbour, B. M. (1992). Enhancing geographical enquiry and learning. *International Research in Geographical and Environmental Education, 1*(1), 14-23.

Watkins, C., Carnell, E., Lodge, C., Wagner, P. & Whalley, C. (2002). 'Effective Learning'. Institute of Education, London University. *NSIN Research Matters*, Summer 2002. Retrieved from http://eprints.ioe.ac.uk/2819/1/Watkins2002Effective.pdf.

Newby, T. J., Stepich, D., Lehman, J. & Russell, J. D. (2005). *Educational Technology for Teaching and Learning* (3rd ed.): Prentice Hall.

Newmann, F. M. (1990). Higher order thinking in teaching social studies: A rationale for the assessment of classroom thoughtfulness. *Journal of Curricular Studies, 22*(3), 253-275.

Nielsen, C. P., Oberle, A. & Sugumaran, R. (2011). Implementing a high school level geospatial technologies and spatial thinking course. *Journal of Geography, 110*, 60-69.

Nilson, L. B. (2010). *Teaching at It's Best: A Research-based Resource for College Instructors (3rd Ed)*. San Francisco, CA.: A Wiley Imprint, Jossey-Bass.

Noble, T. (2004). Integrating the Revised Bloom's Taxonomy With Multiple Intelligences: A Planning Tool for Curriculum Differentiation. *Teachers College Record, 106*(1), 193-211.

Ocepek, U., Bosnic, Z., Nancovska Serbec, I. & Rugelj, J. (2013). Exploring the relation between learning style models and preferred multimedia types. *Computers & Education, 69*, 343-355.

Oehrli, J. A., Piacentine, J., Peters, A. & Nanamaker, B. (2011). *Do screencasts really work? Assessing student learning through instructional screencasts*. Paper presented at the ACRL 2011.

Olivia, P. (2009). *Developing the curriculum (7th ed.)*. Boston, MA: Pearson.

Orlich, D., Harder, R., Callahan, R., Trevisan, M. & Brown, A. (2004). *Teaching strategies: A guide to effective instruction (7th ed.)*. Boston, MA: Houghton Mifflin.

Oud, J. (2009). Guidelines for effective online instruction using multimedia screencasts. *Reference Services Review, 37*(2), 164-177. doi:http://dx.doi.org/10.1108/00907320910957206

Paas, F. & Sweller, J. (2014). Implications of cognitive load theory for multimedia. In R. E. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning (2nd Ed)* (pp.27-42). United States of America: Cambridge Unversity Press.

Paik, E. S. & Schraw, G. (2013). Learning with animation and illusions of understanding. *Journal of Educational Psychology, 105*(2), 278-289.

Palmer, D. H. (2009). Student interest generated during an inquiry skills lesson. *Journal of Research in Science Teaching, 46*, 147-165.

Pang, A. (2006). *Geographical Information Systems (GIS) in Education*. Retrieved from http://pbgis.palmbeach.k12.fl.us/cms/images/GIS_WEB_PDF/Geographical_Information_Systems_in Education.pdf

Papadopoulos, P. M., Demetriadis, S. N., Stamelos, I. G. & Tsoukalas, I. A. (2009). Prompting students' context-generating cognitive activity in ill-structured domains: Does the prompting mode affect learning? *Educational Technology Research and Development, 57*, 193-210.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York: Basic Books.

Partnership for 21st Century Skills, The. (2002). *Learning for the 21st Century: A Report and Mile Guide for 21st Century Skills*. Retrieved from http://www.p21.org/storage/documents/P21_Report.pdf

Patall, E. A. (2013). Constructing motivation through choice, interest, and interestingness. *Journal of Educational Psychology, 105*, 522-534.

Patterson, M., Reeve, K. & Page, D. (2003). Integrating geographic information systems into the secondary curricula. *Journal of Geography, 102*(6), 275-281.

Pavlov, I. P. (1897/1902). *The Work of the Digestive Glands*. London: Griffin.

Pavlov, I. P. (1960). *Conditioned reflexes; an investigation of the physiological activity of the cerebral cortex. (G. V. Anrep, Trans.)*. New York: Dover Publications.

Pea, R. D. (1985). Beyond amplification: using the computer to reorganise mental functioning. *Educational Psychologist, 20*(4), 167-182.

Pea, R. D. (2004). The social and technological dimensions of scaffolding and related theoretical concepts for learning, education, and human activity. *Journal of the Learning Sciences, 13*, 423-451.

Pearce, L. D. (2015). Thinking Outside the Q Boxes: Further Motivating a Mixed Research Perspective. In S. Nagy Hesse-Biber & R. B. Johnson (Eds.), *The Oxford Handbook of Multimethod and Mixed Methods Research Inquiry*.

Perkins, D. N. & Unger, C. (1999). Teaching and learning for understanding. In C. M. Reigeluth (Ed.), *Instructional design theories and models* (pp.91-114). Mahwah, NJ:: Lawrence Erlbaum Associates, Inc.

Perkins, N., Hazelton, E., Erickson, J. & Allan, W. (2010). Place-based education and Geographic Information Systems: Enhancing the spatial awareness of middle school students in Maine. *Journal of Geography, 109*(5), 213-218.

Peterson, P. L. (1988). Teaching for higher order thinking in mathematics: The challenge for the next decade. . In D. A. Grows & T. J. Cooney (Eds.), *Perspectives on research on ewective mathematical learning*. (Vol. 1, pp.2-26). Reston, VA: Lawrence Erlbaum Associates.

Pham, H. (2011). Theory-Based Instructional Models Applied in Classroom Contexts. *Literacy Information and Computer Education Journal (LICEJ), 2*(2), 406-415.

Piaget, J. (1973). *Main Trends in Psychology*. London: George Allen & Unwin.

Piaget, J., Bärbel, I., Weaver, H. & Inhelder, B. (1972). *The Psychology of the Child*: Basic Books.

Pinder-Grover, T., Green, K. & Millunchick, J. M. (2011). The efficacy of screencasts to address the diverse academic needs of students in a large lecture course. *Advances in Engineering Education, 2*(3).

Pinder-Grover, T., Green, K. R. & Millunchick, J. M. (2008). *Work in progress: Using screencasts to enhance student learning in a large lecture Materials Science and Engineering course*. Paper presented at the 38th IEEE/ASEE Frontiers in Education Conference, Saratoga Springs, New York. http://fie-conference.org/fie2008/papers/1362.pdf

Pinder-Grover, T., Millunchick, J. M., Bierwert, C. C. & Shuller, L. (2009). *Leveraging Screencasts to Strategically Clarify Unclear Materials Science Concepts*. Paper presented at the American Society of Engineering Education Annual Conference and Exposition, Austin, Texas, USA. http://tinyurl.com/ol7lm82

Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J., Fretz, E. & Duncan, R. G. (2004). A scaffolding design framework for software to support science inquiry. *Journal of the Learning Sciences, 13*, 337-386.

Raes, A., Schellens, T., Wever, B. D. & Vanderhoven, E. (2012). Scaffolding information problem solving in web-based collaborative inquiry learning. *Computers & Education, 59*, 82-94.

Raftery, D. (2011). Developing educational screencasts: A practitioner's perspective *Instructional design: concepts, methodologies, tools and applications* (Vol. 2, pp.665-678). Hershey, PA: Information Science Reference.

Ratinen, I. & Keinonen, T. (2011). Student-teachers' use of Google Earth in problem-based geology learning. *International Research in Geographical and Environmental Education, 20*(4), 345-358.

Raudenbush, S. W., Rowan, B. & Cheong, Y. F. (1993). Higher order instructional goals in secondary schools: Class, teacher, and school influences. *American Educational Research Journal, 30*, 523-555.

Razik, R., Mammo, Z., Gill, H. S. & Lam, W. C. (2011). Academic screencasting: internet-based dissemination of ophthalmology grand rounds. *Canadian Journal of Ophthalmology/Journal Canadien d'Ophtalmologie, 46*(1), 72-76.

Reed, S. K. (2010). Cognitive architectures for multimedia learning. *Educational Psychologist, 41*(2), 87-98.

Reid, D. J., Zhang, J. & Chen, Q. (2003). Supporting scientific discovery learning in a simulation environment. *Journal of Computer Assisted Learning, 19*, 9-20.

Reigeluth, C. M. (1999). What is instructional-design theory and how is it changing? In C. M. Reigeluth (Ed.), *Instructional-design theories and models* (Vol. 2, pp.5-29). Mahwah, NJ: Erlbaum.

Reiser, B. J. (2004). Scaffolding Complex Learning: The Mechanisms of Structuring and Problematizing Student Work. *The Journal of the Learning Sciences, 13*(3), 273-304.

Reiser, B. J., Tabak, I., Sandoval, W. A., Smith, B. K., Steinmuller, F. & Leone, A. J. (2001). BGuILE: Strategic and conceptual scaffolds for scientific inquiry in biology classrooms. In S. M. Carver & D. Klahr (Eds.), *Cognition and instruction: Twenty-five years of progress* (pp.263-305). Mahwah, NJ: Lawrence-Erlbaum Associates Inc.

Renkl, A. (2005). The worked-out examples principle in multimedia learning *Cambridge Handbook of Multimedia Learning* (pp.229-245). Cambridge: Cambridge University Press.

Richey, R. C. & Klein, J. D. (2008). Research on design and development. In J. M. Spector, J. V. Merrienboer & M. P. Driscoll (Eds.), *Handbook on research on educational communications and technology* (3rd ed., pp.748-757). New York: Routledge.

Riihela, J. & Maki, S. (2015). Designing and Implementing an Online GIS Tool for Schools: The Finnish Case of the PaikkaOppi Project. *Journal of Geography, 114*(1), 15-25.

Rittle-Johnson, B., Siegler, R. S. & Wagner Alibali, M. (2001). Developing Conceptual Understanding and Procedural Skill in Mathematics: An Iterative Process. *Journal of Educational Psychology, 93*(2), 346-362.

Roberts, M. (2003). *Learning through enquiry: Making sense of geography in the key stage 3 classroom*. Sheffield: Geographical Association.

Rød, J. K., Larsen, W. & Nilsen, E. (2010). Learning geography with GIS: Integrating GIS into upper secondary school gegoraphy curricula. *Norsk Geografisk Tidsskrift, 64*(6), 21-35.

Roehler, L. R. & Cantlon, D. J. (1997). Scaffolding: A powerful tool in social constructivist classrooms. In K. Hogan & M. Pressley (Eds.), *Scaffolding Student Learning: Instructionl Approaches and Issues*. Cambridge, MAs: Brookline.

Rose, K. K. (2009). Student Perceptions of the Use of Instructor-Made Videos in Online and Face-to-Face Classes. *MERLOT Journal of Online Learning and Teaching, 5*(3).

Rotgans, J. I. & Schmidt, H. G. (2011). The role of teachers in facilitating situational interest in an active-learning classroom. *Teaching and Teacher Education, 27*, 37-42.

Royal Geographical Society with the Institute of British Geographers. (2015). Geography in the UK. Retrieved from http://www.rgs.org/GeographyToday/Geography+in+the+UK.htm

Ryder, R. J., Burton, J. L. & Silberg, A. (2006). Longitudinal study of direct instruction effects from first through third grade. *Journal of Educational Research, 99*(3), 179-191.

Salomon, G., Perkins, D. N. & Globerson, T. (1991). Partners in cognition: extending human intelligence with intelligence technologies. *Educational Researcher, 20*(3), 2-9.

Scammon, D. L., Tomoaia-Cotisel, A., Day, R. L., Day, J., Kim, J., Waitzman, N. J., . . . Magill, M. K. (2013). Connecting the Dots and Merging Meaning: Using Mixed Methods to Study Primary Care Delivery Transformation. *Health Services Research, 48*, 2181-2207.

Schleicher, A. (2010). The case for 21st-century learning. Retrieved from http://www.oecd.org/general/thecasefor21st-centurylearning.htm

Schnotz, W. (2014). Integrated model of text and picture comprehension. In R. E. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning (2nd Ed)* (pp.72-103). United States of America: Cambridge University Press.

Schunk, D. H. (2008). Cognition and instruction *Learning theories: An education perspective* (pp.278-323). Upper Saddle River, NY: Pearson.

Schwartz, D., Chase, C., Oppezzo, M. & Chin, D. (2011). Practising versus inventing with contrasting cases: the effects of telling first on learning and transfer. *Journal of Educational Psychology, 103*, 759-775.

Sharma, P. & Hannafin, M. (2007). Scaffolding in technology-enhanced learning environments. *Interactive Learning Environments, 15*(1), 27-46. doi:10.1080/10494820600996972

Shin, E-k. (2007). Using Geographic Information Systems (GIS) Technology to Enhance Elementary Students' Geographic Understanding. *Theory and Research in Social Education, 35*(2), 231-255.

Shin, S., Brush, T. & Glazewski, K. (2017). Designing and Implementing Web-based Scaffolding Tools for Technology Enhanced Socioscientific Inquiry. *Educational Technology & Society, 20*(1), 1-12.

Shuell, T. (2013). *Theories of Learning*. Retrieved from http://www.education.com/reference/article/theories-of-learning/

Shulman, L. S. & Keisler, E. R. (1966). *Learning by discovery*. Chicago: Rand McNally.

Simons, K. D. & Klein, J. D. (2007). The Impact of scaffolding and student achievement levels in a problem-based learning environment. *Instructional Science, 35*, 41-72.

Simons, K. D., Klein, J. D. & Brush, T. (2004). Instructional strategies utilized during the implementation of a hypermedia, problem-based learning environment: A case study. *Journal of Interactive Learning Research, 15*, 213-233.

Simons, L. & Lathlean, J. (2010). Mixed Methods. In K. Gerrish & A. Lacey (Eds.), *The Research Process in Nursing* (6th ed.). London: Wiley-Blackwell.

Sinha, G., Smucker, T. A., Lovell, E. J., Velempini, K., Miller, S. A., Weiner, D. & Wangui, E. E. (2017). The Pedagogical Benefits of Participatory GIS for Geographic Education. *Journal of Geography, 116*(4), 165-179. doi:10.1080/00221341.2016.1215488

Sinton, D. (2009). Roles for GIS within Higher Education. *Journal of Geography in Higher Education, 33*(S1), S7-S16.

Sinton, D., Bednarz, S., Gersmehl, P., Kolvoord, R. & Uttal, D. (2013). *The people's guide to spatial thinking*. Washington DC: National Council for Geographic Education.

Sinton, D. & Lund, J. J. (2007). *Understanding Place*. Redlands, CA: ESRI Press.

Skinner, B. F. (1936). Conditioning and extinction and their relation to drive. *Journal of General Psychology, 14*, 296-317.

Skinner, B. F. (1938). *The Behaviour of Organisms: An Experimental Analysis*. New York: Appleton-Century.

Slavin, R. E. (1993). Ability Grouping in the Middle Grades: Achievement Effects and Alternatives *Elementary School Journal, 93*(5), 535-552.

Small, J. (2010). Delivering library instruction with screencast software: A Jing is worth a thousand words. *Health Inform, 19*(3), 15-20.

Sotto, E. (2007). *When Teaching Becomes Learning: A Theory and Practice of Teaching (2nd ed.)*. London: Continuum.

Spatial Industries Business Association (2016). *Future Growth of the Spatial Industries: Position Paper*. Retrieved from http://www.siba.com.au/getattachment/8c451e15-5ca5-43c4-9060-0930f908e153/Spatial-Industry-Strategic-Plan-2016-Final2.pdf

Spiro, R. J. & DeSchryver, M. (2009). Constructivism: When it's the wrong idea and when it's the only idea. In S. E. Tobias & T. M. E. Duffy (Eds.), *Constructivist instruction: Success or failure?* (pp.376). New York, NY: Routledge/Taylor & Francis Group.

Spooner, F., Jordan, L., Algozzine, B. & Spooner, M. (1999). Student Ratings of Instruction in Distance Learning and On-Campus Classes. *The Journal of Educational Research, 92*(3), 132-140.

Srivastava, S. K. & Tait, C. (2012). An Activity-Based Learning Approach for Key Geographical Information Systems (GIS) Concepts. *Journal of Geography in Higher Education, 36*(4), 527-545.

Stavredes, T. (2011). *Effective online teaching: Foundations and strategies for student success.* Retrieved from

Steffe, L. & Gale, J. (Eds.). (1995). *Constructivism in education*. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Sternberg, R. & Lubart, T. (1996). Investing in creativity. *American Psychologist, 51*(7), 677-688.

Stowell, J. R. (2010). Effects of Online Testing on Student Exam Performance and Test Anxiety. *Journal of Educational Computing Research, 42*(2), 161-171.

Strand-Cary, M. & Klahr, D. (2008). Developing elementary science skills: instructional effectivenss and path independence. *Cognitive Development, 23*, 488-511.

Sugar, W., Brown, A. & Luterbach, K. (2010). Examining the Anatomy of a Screencast: Uncovering Commonm Elements and Instructional Strategies. *International Review of Research in Open and Distance Learning, 11*(3).

Sui, D. Z. (1995). A Pedagogic Framework to Link GIS to the Intellectual Core of Geography. *Journal of Geography, 94*(6), 578-591.

Suk Kim, J. (2005). The Effects of Constructivist Teaching Approach on Student Academic Achievement, Self-Concept, and Learning Strategies. *Asia Pacific Education Review, 6*(1), 7-19.

Surgenor, P. (2010). *How Students Learn 1*. Retrieved from Dublin, Ireland: http://www.ucd.ie/t4cms/UCDTLT0016.pdf

Sutton-Brady, C., Scott, K., Taylor, L., Carabetta, G. & Clark, S. (2009). The value of using short-format podcasts to enhance learning and teaching. *ALT-J, 17*(3), 219-232.

Sweller, J. (2003). Evolution of human cognitive architecture. In B. Ross (Ed.), *The psychology of learning and motivation* (Vol. 43, pp.215-266). San Diego, CA: Academic.

Sweller, J. (2005). Implications of cognitive load theory from multimedia learning. In R. E. Mayer (Ed.), *Cambridge handbook of multimedia learning* (pp.19-32). Cambridge: Cambridge University Press.

Sweller, J., Ayres, P. & Kalyuga, S. (2011). *Cognitive load theory*. New York: Springer.

Tabak, I. (2004). Synergy: a complement to emerging patterns of distributed scaffolding. *Journal of the Learning Sciences, 13*(3), 305-335.

Teddlie, C. & Tashakkori, A. (2003). *Mixed methodology: Combining qualitative and quantitative approaches*. Thousand Oaks, CA: SAGE.

Teddlie, C. & Tashakkori, A. (2009a). *Foundations of mixed methods research: Integrating quantitative and qualitative approaches in the social and behavioral sciences*. Thousand Oaks, CA: SAGE.

Teddlie, C. & Tashakkori, A. (Eds.). (2009b). *Foundations of mixed methods research*. Thousand Oaks, CA: Sage.

Tempelman-Kluit, N. (2006). Multimedia learning theories and online instruction. *College & Research Libraries, 67*(4), 364-369.

Tewell, E. (2010). Video tutorials in academic art libraries: A content analysis and review. *Art Documentation: Journal of the Art Libraries Society of North America, 29*(2), 53-61.

Thompson, R. & Lee, M. J. (2012). Talking with students through screencasting: experimentations with video feedback to improve student learning. *The Journal of Interactive Technology and Pedagogy, 1*(1).

Thorndike, E. L. (1905). *The elements of psychology*. New York: Seiler.

Tomlinson, R. (2012). Foreword. *International Perspectives on Teaching and Learning with GIS in Secondary Schools* (p.v). Dordrecht, Heidelberg, London, New York: Springer Science+Business Media B. V. .

Trautmann, N. M. & MaKinster, J. G. (2014). Meeting teachers where they are and helping them achieve their geospatial goals. In J. G. MaKinster, N. M. Trautmann & M. Barnett (Eds.), *Teaching science and investigating environmental issues with geospatial technology: Designing effective professional development for teachers*. Dordrecht, NE: Springer.

Tuovinen, J. & Sweller, J. (1999). Comparison of cognitive load associated with discovery learning and worked examples. *Journal of Educational Psychology, 91*, 334-341.

van der Schee, J. (2003). New media will accelerate the renewal of geographical education. In R. Gerber (Ed.), *International handbook on geographical education* (pp.205-214): Dordrecht: Kluwer.

Vang, C. T. (2005). Minority Students are Far from Academic Success and Still At-Risk in Public Schools. *Multicultural Education, 12*(4), 9-15.

Vogel-Walcutt, J. J., Gebrim, J. B., Bowers, C., Carper, T. M. & Nicholson, D. (2011). Cognitive load theory vs. constructivist approaches: which best leads to efficient, deep learning? *Journal of Computer Assisted Learning, 27*(2), 133-145.

von Glasersfeld, E. (1989). Constructivism in Education. In T. Husen & N. Postlethwaite (Eds.), *International Encyclopedia of Education* (Vol. Supplementary Vol, pp.162-163): Oxford: Pergamon.

Vreman-de Olde, C. & de Jong, T. (2006). Scaffolding learners in designing investigation assignments for a computer simulation. *Journal of Computer Assisted Learning, 22*, 63-73.

Vygotsky, L. S. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.

Wagner, T., Baum, L. & Newbill, P. (2014). From rhetoric to real world: fostering higher order thinking through transdisciplinary collaboration. *Innovations in Education and Teaching International, 51*(6), 664-673. doi:10.1080/14703297.2013.796726

Walden University. (2010). *Educators, Technology and 21st Century Skills: Dispelling Five Myths: A Study on the Connection Between K–12 Technology Use and 21st Century Skills*. Retrieved from https://www.waldenu.edu/-/media/Walden/general-media/about-walden/colleges-and-schools/riley-college-of-education/educational-research/full-report-dispelling-five-myths.pdf?la=en

Wanner, S. & Kerski, J. J. (1999). *The effectiveness of GIS in high school education*. Paper presented at the ESRI User Conference, San Diego, USA.

Watanabe, M. (2006). "Some People Think This School Is Tracked and Some People Don't": Using Inquiry Groups to Unpack Teachers' Perspectives on Detracking. *Theory into Practice, 45*(1), 24-31.

Watson, J. B. (1913). Psychology as the behaviorist views it. *Psychological Review, 20*, 158-177.

West, B. A. (1998). GIS in the secondary school: Some possible outcomes. *Geographical Education, 11*, 12-17.

West, B. A. (2003). Student Attitudes and the Impact of GIS on Thinking Skills and Motivation. *Journal of Geography, 102*(6), 267-274. doi:10.1080/00221340308978558

West, B. A. (2008). *Conceptions of geographical information systems (GIS) held by Senior Geography Students in Queensland*. (Doctor of Philosophy), Queensland University of Technology.

Wheeler, P., Gordon-Brown, L., Peterson, J. & Ward, M. (2010). Geographical information systems in Victorian secondary schools: current constraints and opportunities. *International Research in Geographical and Environmental Education, 19*(2), 155-170.

White, B. Y. & Frederiksen, J. R. (1998). Inquiry, modeling and metacognition: Making science accessible to all students. *Cognition and Instruction, 16*(1), 3-118.

White, B. Y. & Frederiksen, J. R. (2000). Metacognitive facilitation: An approach to making scienti"c inquiry accessible to all. In J. L. Minstrell & E. H. Van-Zee (Eds.), *Inquiry into inquiry learning and teaching in science* (pp.331-370). Washington DC.: American Association for the Advancement of Science.

White, K. L. & Simms, M. (1993). Geographic Information Systems as an educational tool. *Journal of Geography, 92*(2), 80-85.

Wigglesworth, J. (2003). What is the best route? Route-finding strategies of middle school students using GIS. *Journal of Geography, 102*(6), 282-291.

Williams, L. & Lahman, M. (2011). Online Discussion, Student Engagment, and Critical Thinking. *Journal of Political Science Education, 7*(2), 143-162.

Wilson, B. G. (2005). Broadening our foundation of instructional design: Four pillars of practice. *Educational Technology, 45*(2), 10-15.

Wilson, L. O. (2013). The Second Principle: Anderson and Krathwohl - Bloom's Taxonomy Revised. Retrieved from http://thesecondprinciple.com/teaching-essentials/beyond-bloom-cognitive-taxonomy-revised/

Wisdom, J. P., Cavaleri, M. A., Onwuegbuzie, A. J. & Green, C. A. (2012). Methodological reporting in qualitative, quantitative and mixed methods health services research articles. *Health Services Research, 47*, 721-745.

Wood, D., Bruner, J. S. & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 17*, 89-100.

Wouters, P., Paas, F. & van Merrienboer, J. G. (2008). How to optimise learning from animated models: A review of guidelines based on cognitive load. *Review of Educational Research, 78*(3), 645-675.

Yee, M. H., Yunos, J. B. M., Othman, W. B., Hassan, R. B., Tee, T. K. & Mohamad, M. M. B. (2014, 5th–6th November 2014). *Disparity of Learning Styles and Higher Order Thinking Skills among Technical Students*. Paper presented at the 4th World Congress on Technical and Vocational Education and Training (WoCTVET), Malaysia.

Yilmaz, K. (2011). The Cognitive Perspective on Learning: Its Theoretical Underpinnings and Implications for Classroom Practices. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 84*(5), 204-212.

Zhang, W. & Creswell, J. (2013). The use of “mixing” procedure of mixed methods in health services research. *Medical Care, 51*, e51-57.

Zohar, A. (1999). Teachers' metacognitive knowledge and the instruction of higher order thinking. *Teaching and Teacher Education, 15*, 413-429.

Zohar, A. (2006). Connected Knowledge in Science and Mathematics Education. *International Journal of Science Education, 28*(13), 1579-1599. doi:10.1080/09500690500439199

Zohar, A., Degani, A. & Vaaknin, E. (2001). Teachers' beliefs about low-achieving students and higher order thinking. *Teaching and Teacher Education, 17*, 469-485.

Zohar, A. & Dori, Y. J. (2003). Higher Order Thinking Skills and Low-Achieving Students: Are They Mutually Exclusive? *The Journal of the Learning Sciences, 12*(2), 145-181.

Zou, P. X. W., Sunindijo, R. Y. & Dainty, A. R. J. (2014). A mixed methods research design for bridging the gap between research and practice in construction safety. *Safety Science, 70*, 316-326.

Appendix A: Direct Instruction and Guided Discovery student worksheets for the Energy and Development topics

Direct Instruction

DEVELOPMENT

GIS Activity

Year 9

NAME: ____

GROUP: _______________________

DATE OF BIRTH: _____________________________

Part A - REMEMBER

a) ACTIVITY – Define the following terms

Development

____

____

____

Gross Domestic Product (GDP)

____

____

____

Wealth

____

____

____

b) ACTIVITY – What does the word 'development' refer to? Explain your answer.

____

____

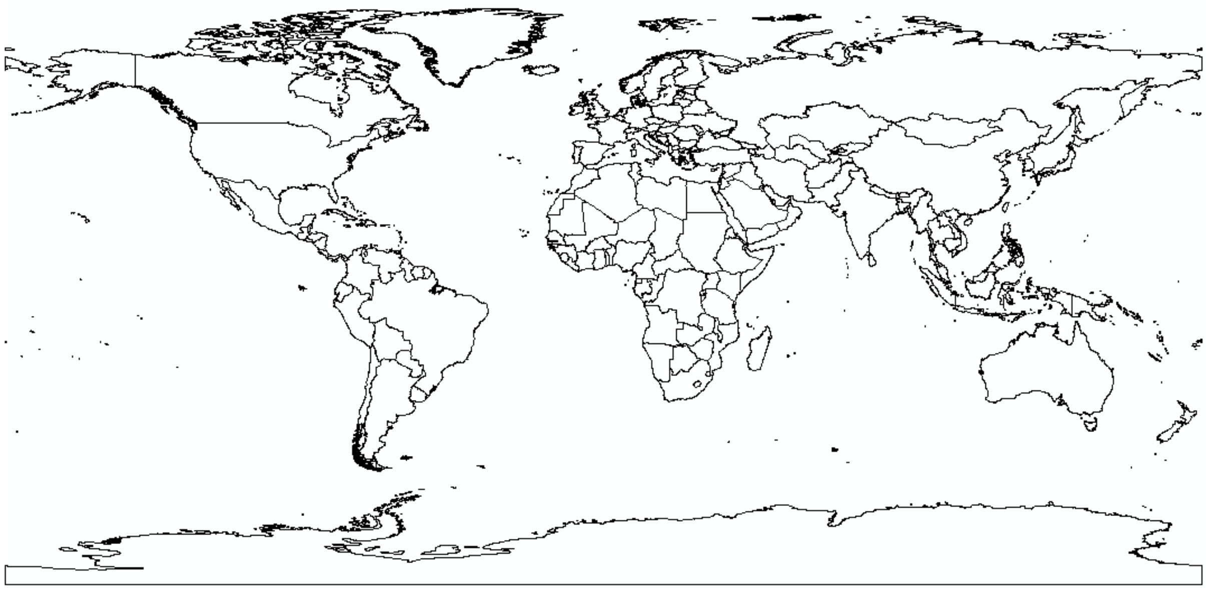
____

____

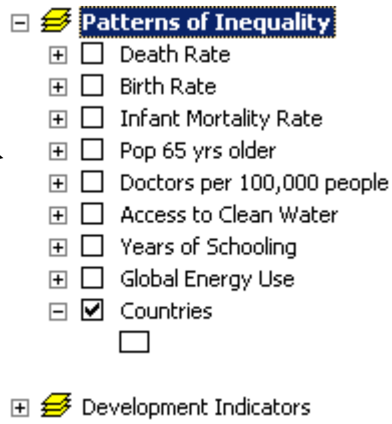
____

Part B - UNDERSTAND

1 – The following should be displayed in **ArcMap**.



Expand **Patterns of Inequality** by clicking the plus sign (+). The following should appear



The ACTIVE data frame is **Patterns of Inequality** and the **Countries** data layer should be turned ON.

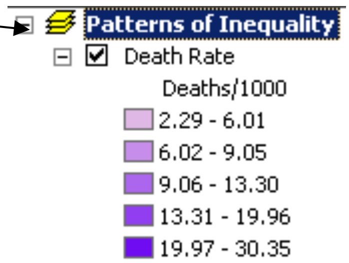
2 – Use the Zoom In and Zoom Out buttons  to explore the data by left clicking on the mouse and dragging a square over an area of interest.

By clicking the + sign next to each of the layers, you can see that they can be turned ON and OFF.

3 – Click the **Zoom to Full Extent** button .

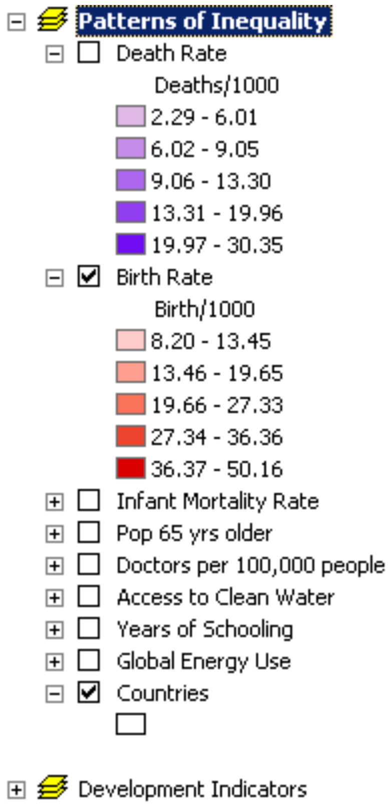
Make sure the **Countries** data layer is the only data layer turned ON.

4 – Expand the **Death Rate** layer (click the + sign)
and turn it ON.



a) ACTIVITY – What could you learn from a map that showed patterns of Death Rates around the world?

5 – Turn OFF **Death Rates** and turn ON **Birth Rates**



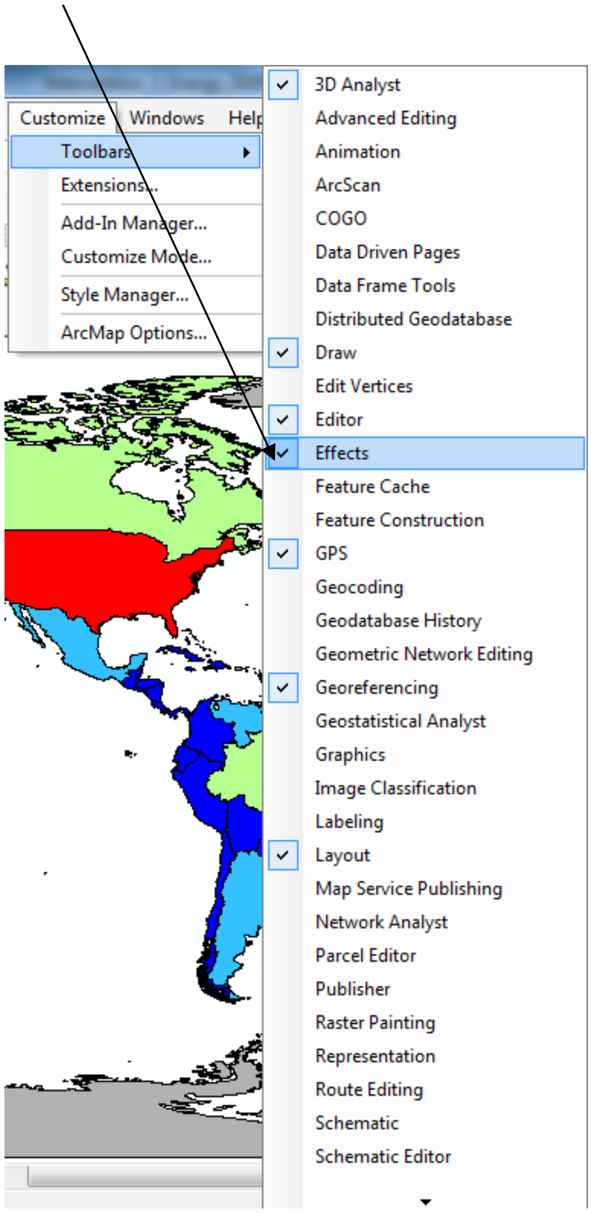
a) ACTIVITY – What could you learn from a map that showed patterns of Birth Rates around the world?

6 – Turn ON the following layers at the same time.

- **Death Rates**
- **Birth Rates**

7 - From the **Customise** menu, select **Toolbars**

From the **Toolbars** that appear click on **Effects**



The **Effects** toolbar should appear. You may like to 'dock' it with the other toolbars at the top of ArcMap.

8 – From the **Effects** dropdown menu, select **Death Rates** as shown

Select the **Swipe** button 

Click and hold the cursor at the top of the map and drag down the map. You should be able to see both **Birth Rates** and **Death Rates** at the same time.

a) ACTIVITY – Describe any similarities OR differences in the patterns of Birth and Death Rates around the world.

____

____

____

____

9 – ACTIVITY – Choose ONE other (<u>different</u>) data layers and answer the questions:

Data Layer: ______________________________

i. Describe the pattern of inequality around the world that your chosen data layer shows.

____

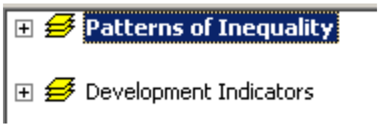
____

____

____

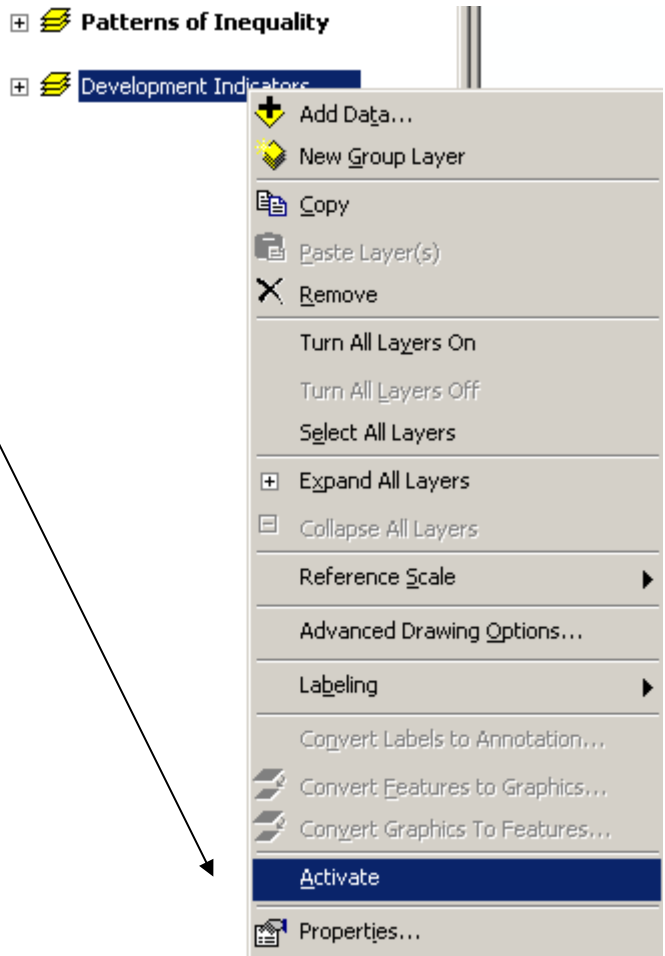
ii. Describe how you think the data layer could be used to determine the level of development of different countries.

10 – Click the Zoom to Full Extent button .
Turn OFF all layers and collapse them by clicking the minus sign (-).
The following should appear



Click the **Select Elements** button  and click **Development Indicators** as shown below

11 – RIGHT CLICK the data frame called **Development Indicators** and click **Activate**

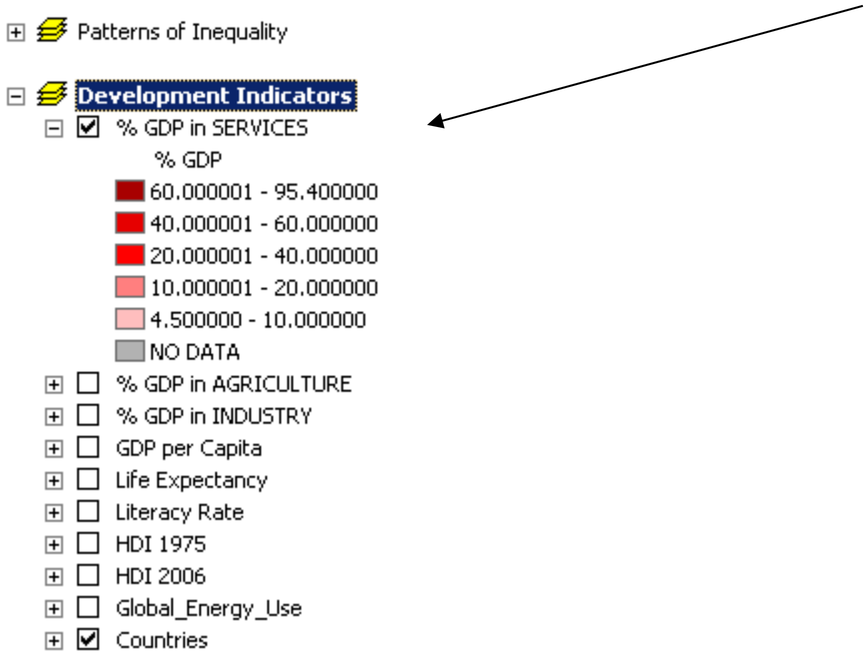


12 – Expand **Development Indicators** (click the +).

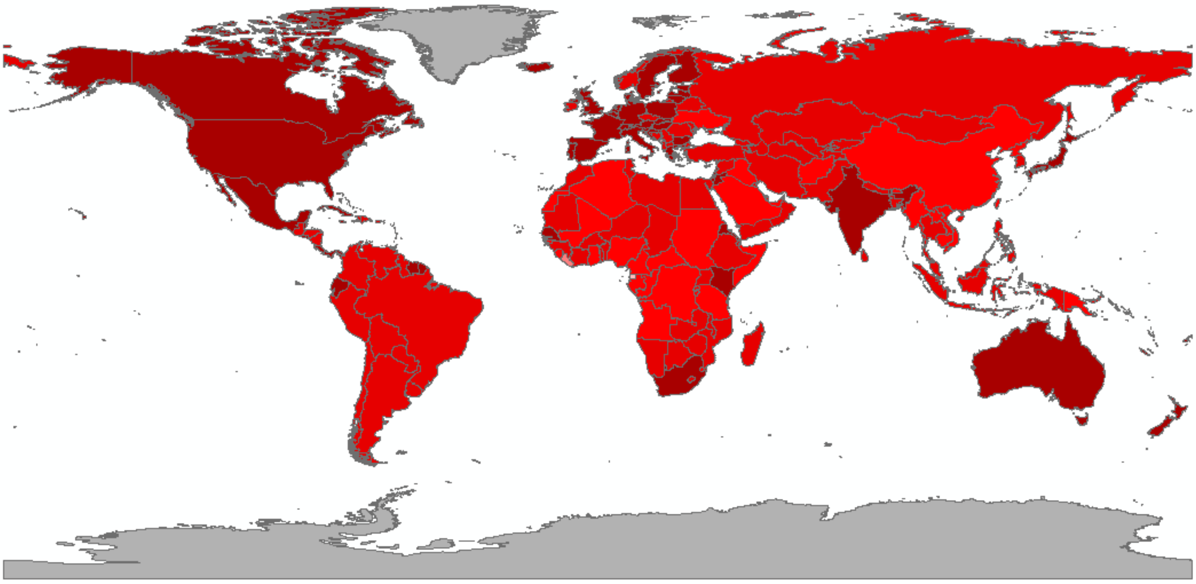
The data frame should look like the following

The display should look like this

13 – Expand and turn ON the layer **% GDP in SERVICES**



The following should appear.



This is a map of the world which shows the contribution of each country's **SERVICE** sector (as a **percentage %**) to **GDP (Gross Domestic Product)**.

The **SERVICE** sector of a country refers to its **Tertiary Industry**. This includes:

- banking, insurance and finance;
- the media and entertainment industries;
- consulting, tourism and retail;
- services provided by government, such as education, health and welfare; and
- other personal and business services.

14 – Complete the table below by answering the questions.

i) Describe the pattern of SERVICES shown on the map

____

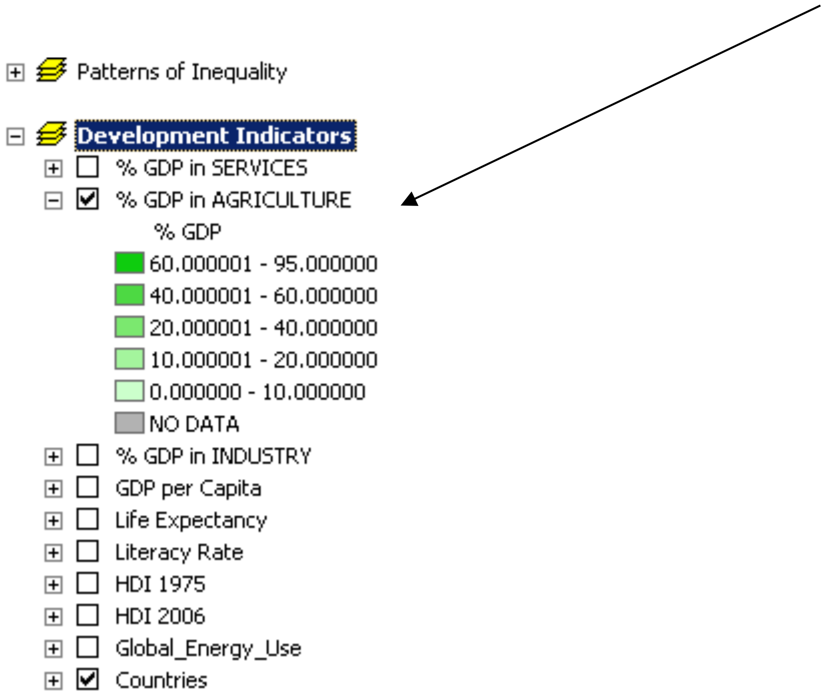
____

____

____

Turn OFF the **% GDP in SERVICES** layer and collapse it by clicking the minus sign (-).

Turn ON the **% GDP in AGRICULTURE** layer and expand it.



ii) Describe the pattern of AGRICULTURE shown on the map

____

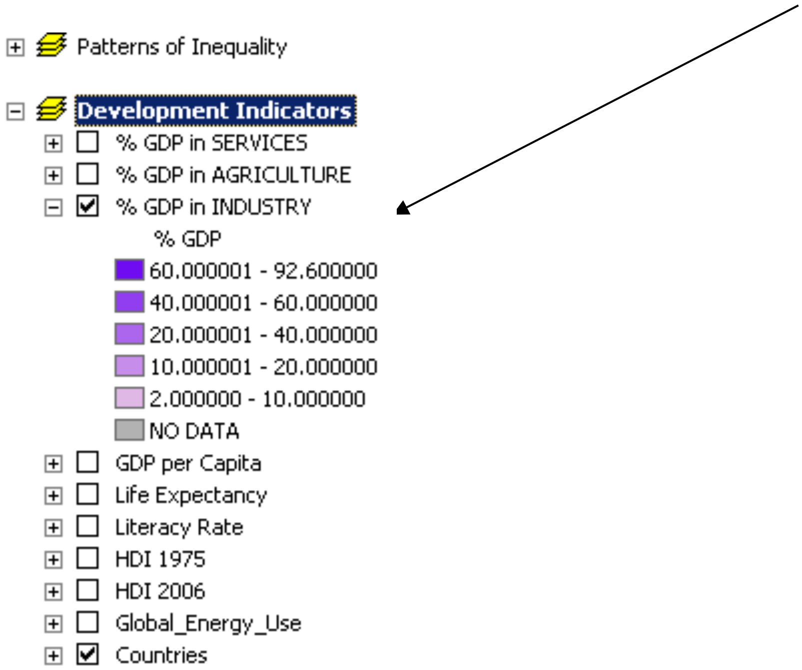
____

____

____

Turn OFF the **% GDP in AGRICULTURE** layer and collapse it by clicking the minus sign (-).

Turn ON the **% GDP in INDUSTRY** layer and expand it.



iii) Describe the pattern of INDUSTRY shown on the map

____

____

____

____

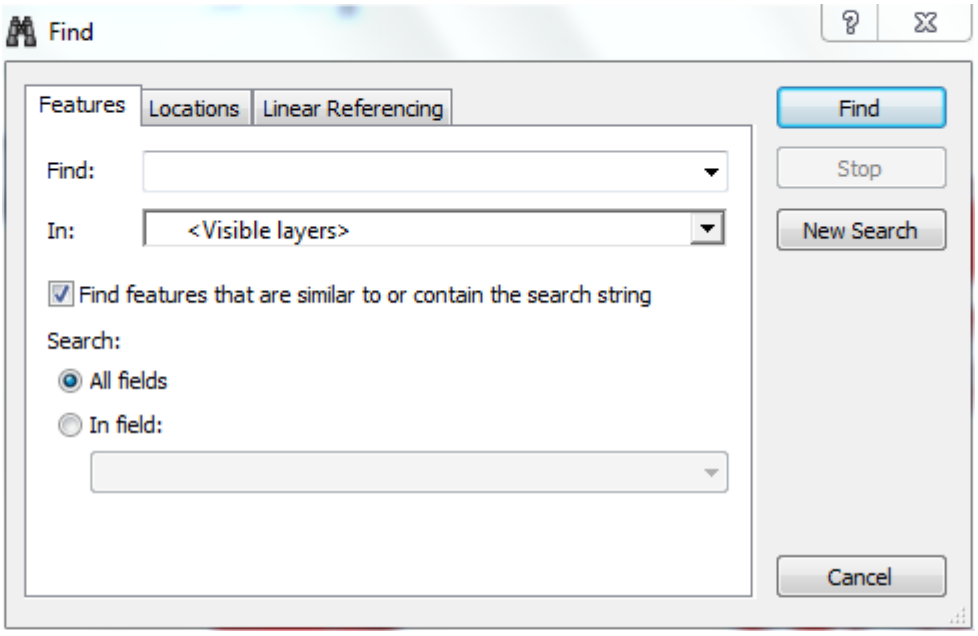
15 – Click the Zoom to Full Extent button  when you are finished.

Collapse and turn off the layers except for **% GDP in SERVICES** and **Countries**.

Now, you will explore the GDP contribution for some selected countries – Ecuador, Saudi Arabia, Australia, China, Ukraine and the Democratic Republic of Congo (DRC).

16 – Select the **Find** tool 

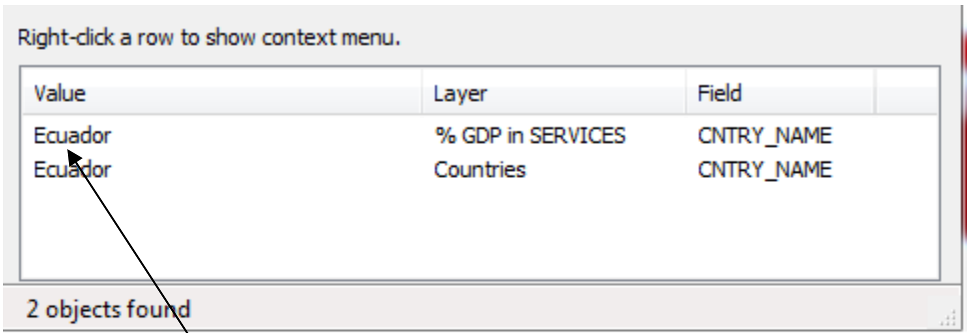
The following should appear.



Click the **Features** tab

Type in Ecuador in the Find field and click **Find**.

Ecuador should appear in a new area below the Find window as shown



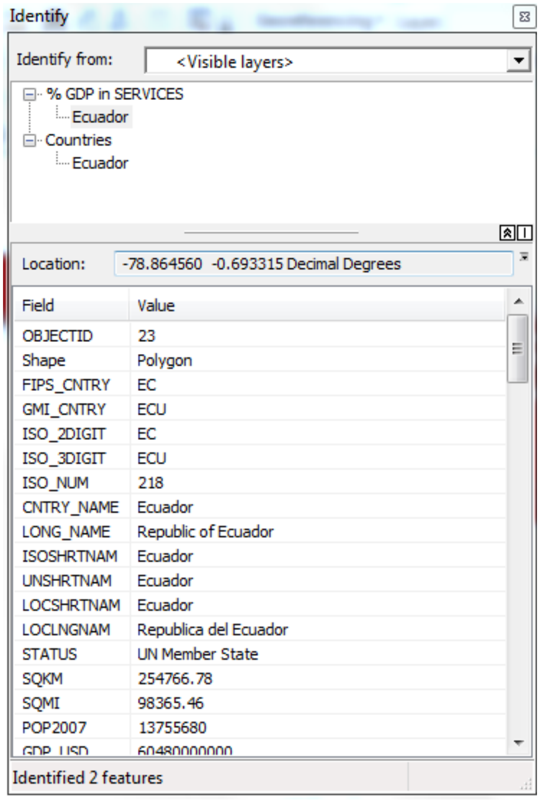
Click on Ecuador.

It should highlight on the map (NOTE: you may have to move the Find window so that Ecuador can be more easily seen).

When you have identified where Ecuador is located, close the Find window.

17 – Select the **Identify** button and click on Ecuador

The following should appear.



Scroll down to find the following information.

PGDP – AG

PGDP – IN

PGDP – SV

(NOTE: AG means Agriculture, IN means Industry, SV means Services)

a) ACTIVITY – In the space provided in the table below, record the % by contribution for each sector in Ecuador.

ECUADOR		**SAUDI ARABIA**		**AUSTRALIA**	
Sector	**%**	**Sector**	**%**	**Sector**	**%**
AGR		AGR	3.3	AGR	3.8
IND		IND	67	IND	26.2
SER		SER	29.8	SER	70
CHINA		**UKRAINE**		**DRC**	
Sector	**%**	**Sector**	**%**	**Sector**	**%**
AGR	11.9	AGR	17.7	AGR	55
IND	48.1	IND	42.7	IND	11
SER	40	SER	39.8	SER	34

b) ACTIVITY – Using this information, indicate (with a tick) whether you think the country is DEVELOPED or DEVELOPING.

COUNTRY	**DEVELOPED?**	**DEVELOPING?**
ECUADOR	□	□
SAUDI ARABIA	□	□
AUSTRALIA	□	□
CHINA	□	□
UKRAINE	□	□
DRC	□	□

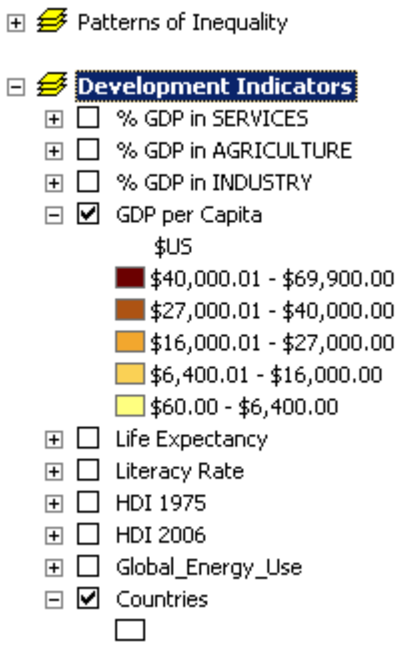
18 – **Close** the **Identify** window.

Turn OFF all layers (except **Countries**) and collapse them. Make sure you have zoomed to the full extent. 

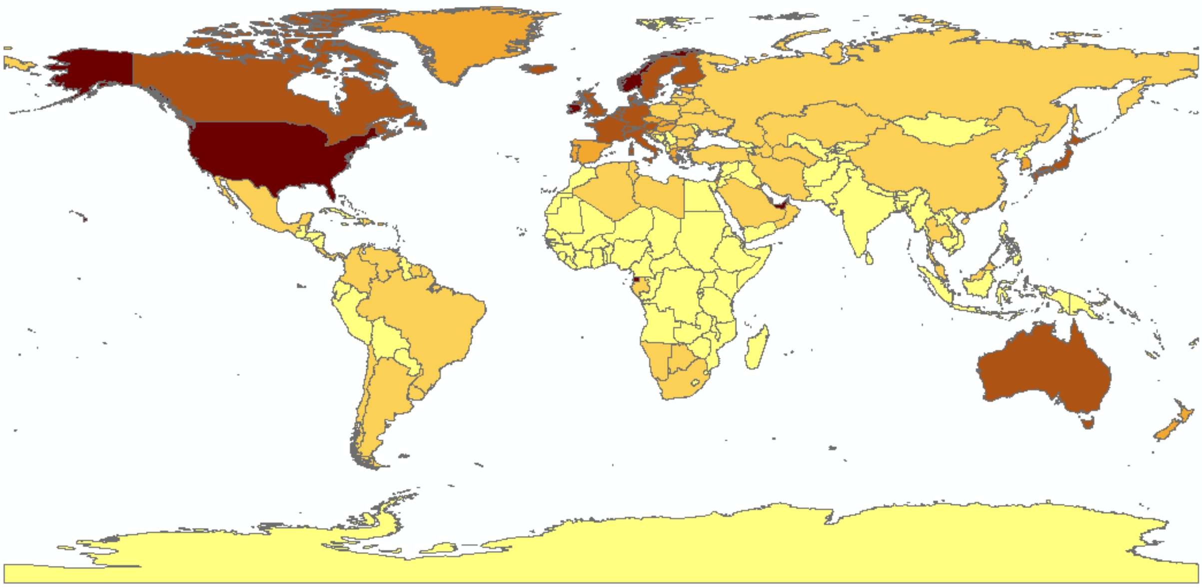
Part C - APPLY

You are still using **Development Indicators** for Part C.

1 – Make sure that **GDP per Capita** and **Countries** are the only layers turned ON and expanded.



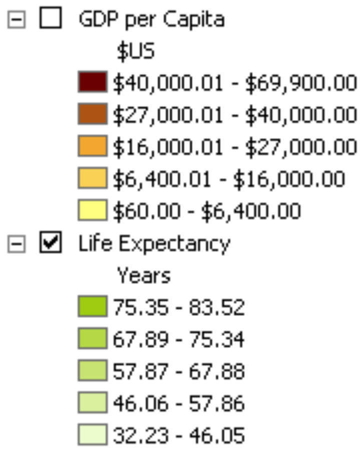
Your map should like the following



a) ACTIVITY – Explain the pattern of GDP around the world.

Turn OFF **GDP per Capita**.

2 – Expand the **Life Expectancy** layer and turn it ON.



a) ACTIVITY – Explain the pattern of life expectancy around the world

3 – Turn ON **GDP per Capita**

From the **Effects** dropdown menu, select **GDP per Capita**

Use the **Swipe Tool** to examine the relationship between **GDP per capita** and **Life Expectancy**

a) ACTIVITY – Is there a link between GDP per capita and Life Expectancy?

Turn OFF **GDP per Capita**

4 – Do the same for Literacy Rates.

a) ACTIVITY – Is there a link between GDP per capita and Literacy Rates?

Part D - ANALYSE

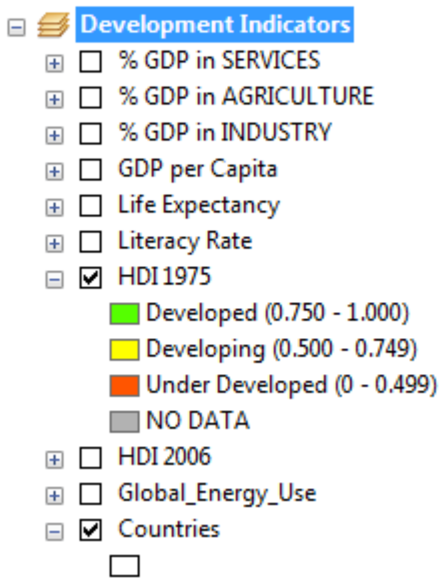
<u>REMEMBER</u>: The Human Development Index (HDI) is a composite measure of social welfare which includes three variables:

- **Life expectancy**
- **Literacy levels**
- **GDP per capita**

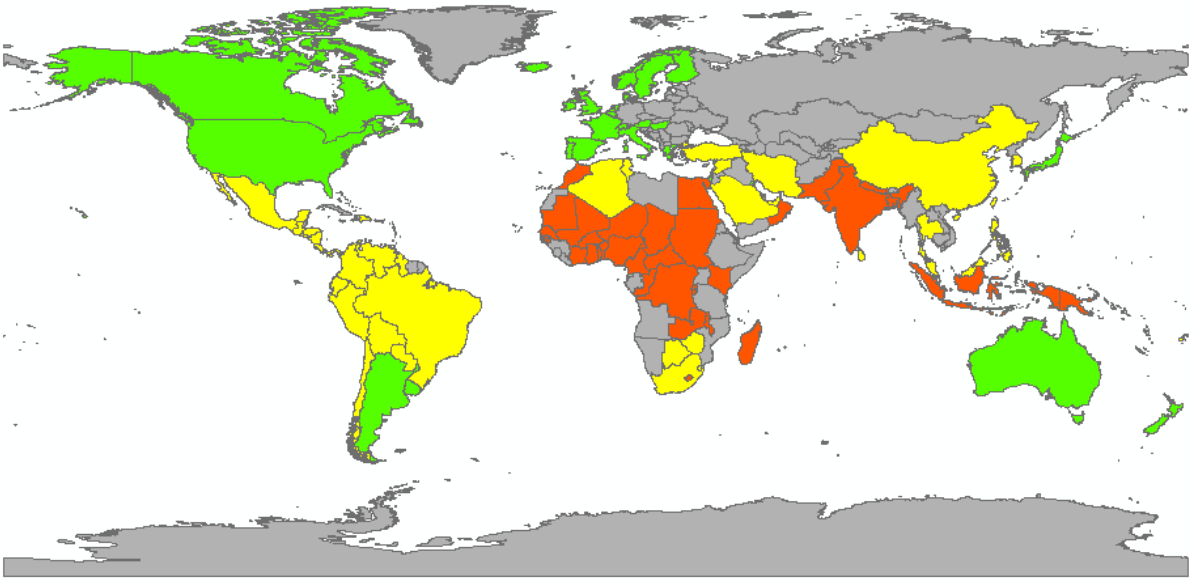
It provides a rank from 0 (low) to 1 (high).

In this exercise, you will compare levels of development as indicated by the Human Development Index for the years 1975 and 2006.

1 – Expand and turn ON the layer **HDI 1975**



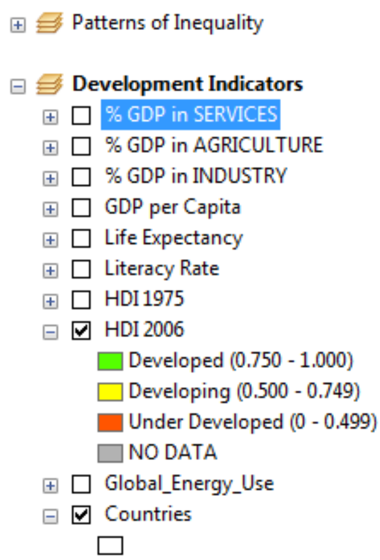
Your map should look like this



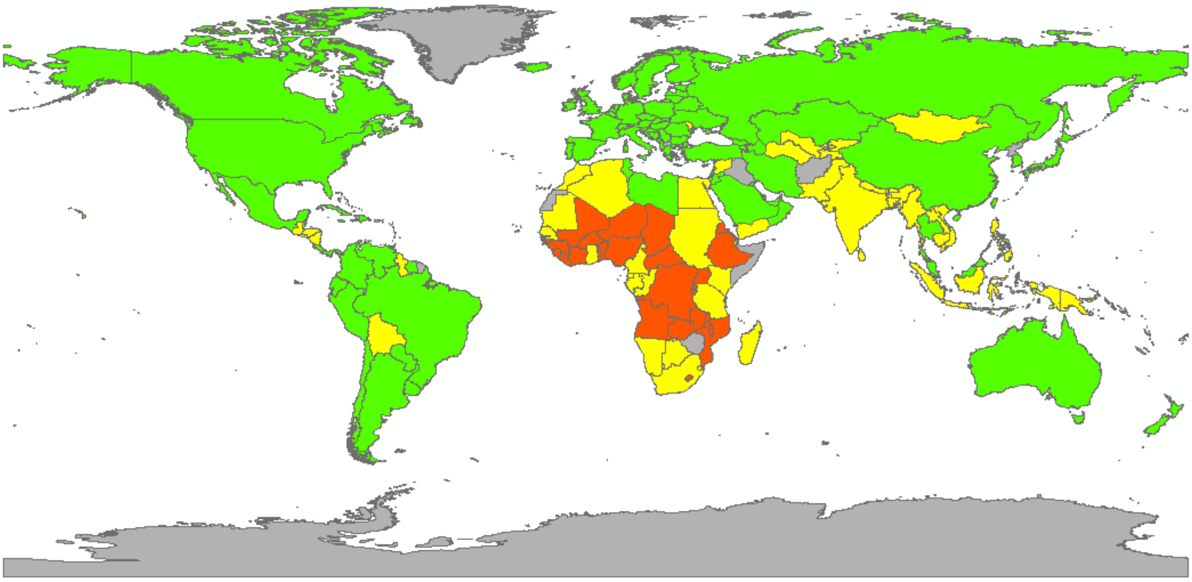
a) In 1975, where was there HIGH and LOW development?

2 – Collapse and turn OFF **HDI 1975.**

Expand and turn ON the layer **HDI 2006**



Your map should appear as follows.



b) In 2006, where was there HIGH and LOW development?

3 – Turn ON and expand the layer **HDI 1975.**

From the **Effects** dropdown menu, select **HDI 1975**

Select the **Swipe** tool  then click and drag the cursor from top to bottom across the map.

a) ACTIVITY – Compare the changes in DEVELOPMENT between 1975 and 2006.

b) ACTIVITY – Can you suggest reasons for this?

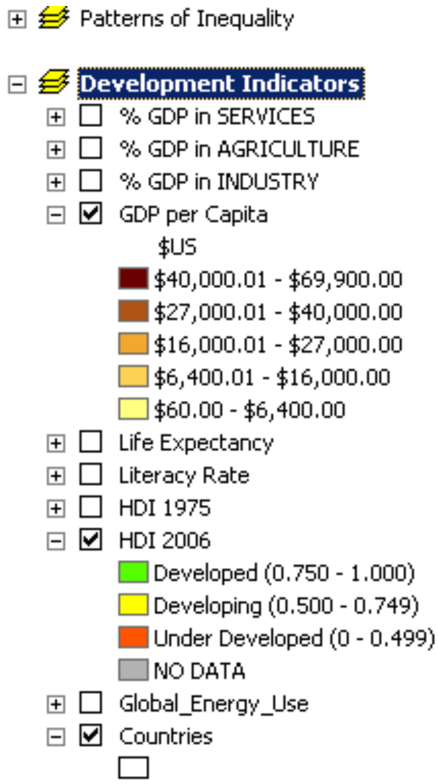
____

____

____

____

4 – Collapse and turn OFF the layer **HDI 1975** but leave ON the layer **HDI 2006**. Turn ON the **GDP per capita** layer.



From the **Effects** dropdown menu, select **GDP per Capita**

Click the **Swipe** tool again then click and drag the cursor from top to bottom across the map.

a) ACTIVITY – Compare the relationship between GDP per capita and HDI 2006?

Part E - EVALUATE

Look at the picture below and respond to the question in the space provided.

A wealthy western company has offered to provide funding to help improve standards of living for people living in an African village. The village is typical of those in many African countries with limited access to the most basic needs including food, clean water and medicine. The company would like its funding to go towards the:

- ***Improvement of mobile phone networks***
- ***Funding for the building of schools***
- ***Medical supplies and drugs for immunisation***
- ***Purchase of computers for schools***
- ***Development of Tourist and safari parks***
- ***Investment in renewable technologies***
- ***Improvement of roads and cycle paths***
- ***Education programs about contraception***

You are an expert at the United Nations specialising in Development issues. It is your job to look carefully at the company's funding proposal and evaluate the strengths and weaknesses of the plan.

Write your response in the space provided below.

Part F - CREATE

As an expert in development issues employed at the United Nations, you are regularly called upon to provide advice about how to measure living standards around the world.
Recently, there has been significant criticism of the 'HUMAN DEVELOPMENT INDEX' with many people now suggesting that it is no longer the best means of measuring development.
As a result, you have been asked by the Secretary-General of the United Nations to develop a different index to measure the quality of life of people living around the world.

You need to:

a) ***Create a new name for the index***
b) ***Outline the criteria that the index is based upon***
c) ***Explain why it is a better measure of human development than the HDI***

Record your responses in the space provided below.

____
____
____
____
____
____
____
____
____
____
____
____
____
____

Guided Discovery

DEVELOPMENT

GIS Activity

Year 9

NAME: ____

GROUP: _______________________

DATE OF BIRTH: _____________________________

Part A - REMEMBER

c) ACTIVITY – With your partner discuss the following terms and write down an appropriate definition

Development

____

____

____

Gross Domestic Product (GDP)

____

____

____

Wealth

____

____

____

ACTIVITY – What do you understand the word 'development' to mean? Explain your answer.

____

____

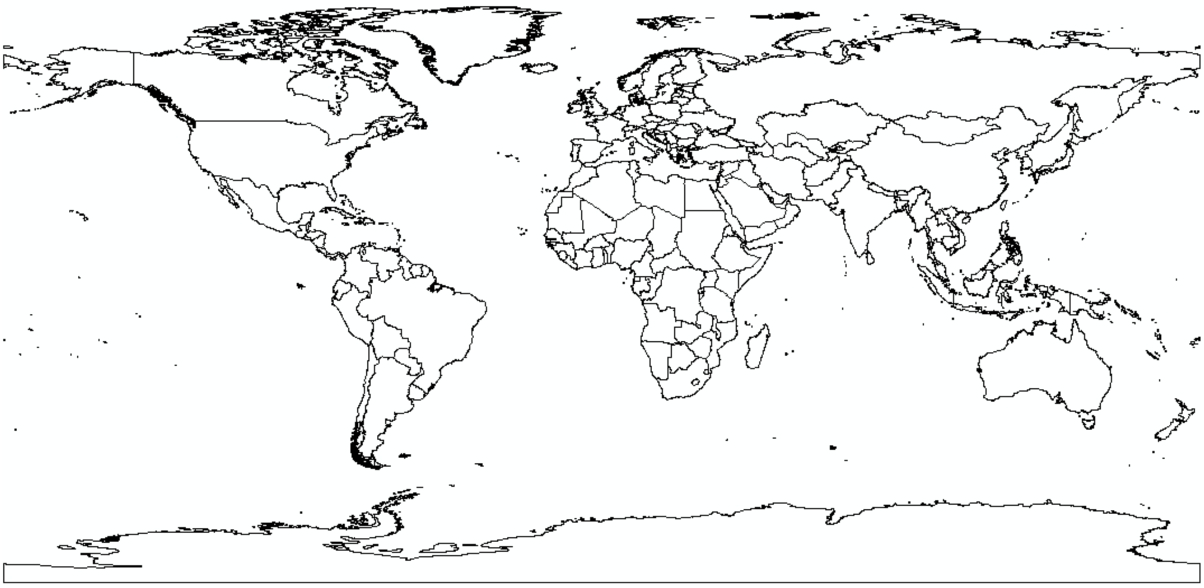
____

____

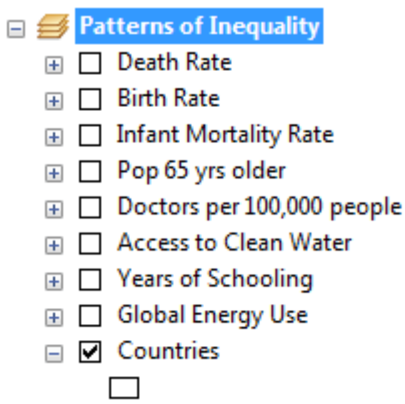
____

Part B - UNDERSTAND

The following should be displayed in **ArcMap**.



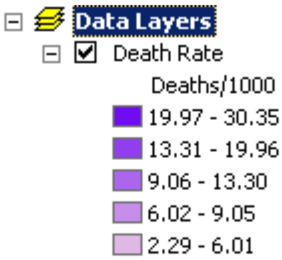
The left-hand side of the screen shows the **Data Layers** with different map layers within it.



<u>How to view the map layers</u>:

- The map layers can be turned on by checking or ticking the box as follows

- The map layer can also be expanded by clicking the plus sign (+)



- All the data displayed is relevant to the topic of **Development.**
- You can explore the different map layers by turning the layers ON and OFF. You should also look at the using the Zoom In and Zoom Out buttons  to explore the data by left clicking on the mouse and dragging a square over an area of interest.

- Click the **Zoom to Full Extent** button .

- Make sure the **Countries** data layer is the only data layer turned ON.

1 – Use the following layers to answer the questions in this section:

- **Birth Rate**
- **Death Rate**

a) ACTIVITY – What could you learn from a map that showed patterns of Death Rates around the world?

____

____

____

____

b) ACTIVITY – What could you learn from a map that showed patterns of Birth Rates around the world?

____

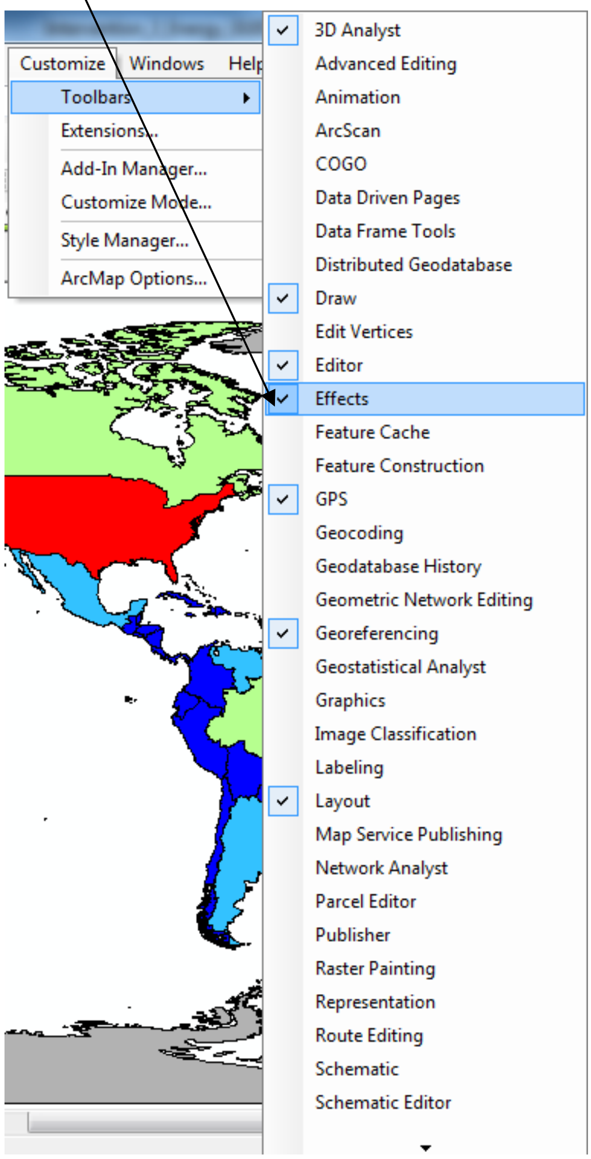
____

____

____

2 - From the **Customise** menu, select **Toolbars**

From the **Toolbars** that appear click on **Effects**



3 – From the **Effects** dropdown menu, select **Death Rates** as shown

Select the **Swipe** button 

Click and hold the cursor at the top of the map and drag down the map. You should be able to see both **Birth Rates** and **Death Rates** at the same time.

a) ACTIVITY – Describe any similarities OR differences in the patterns of Birth and Death Rates around the world.

4 – Select ONE other (<u>different</u>) data layers (other than Birth and Death Rates) and answer the questions:

Data Layer: ____________________________

iii. Describe the pattern of inequality around the world that your chosen data layer shows.

iv. Describe how you think the data layer could be used to determine the level of development of different countries.

____

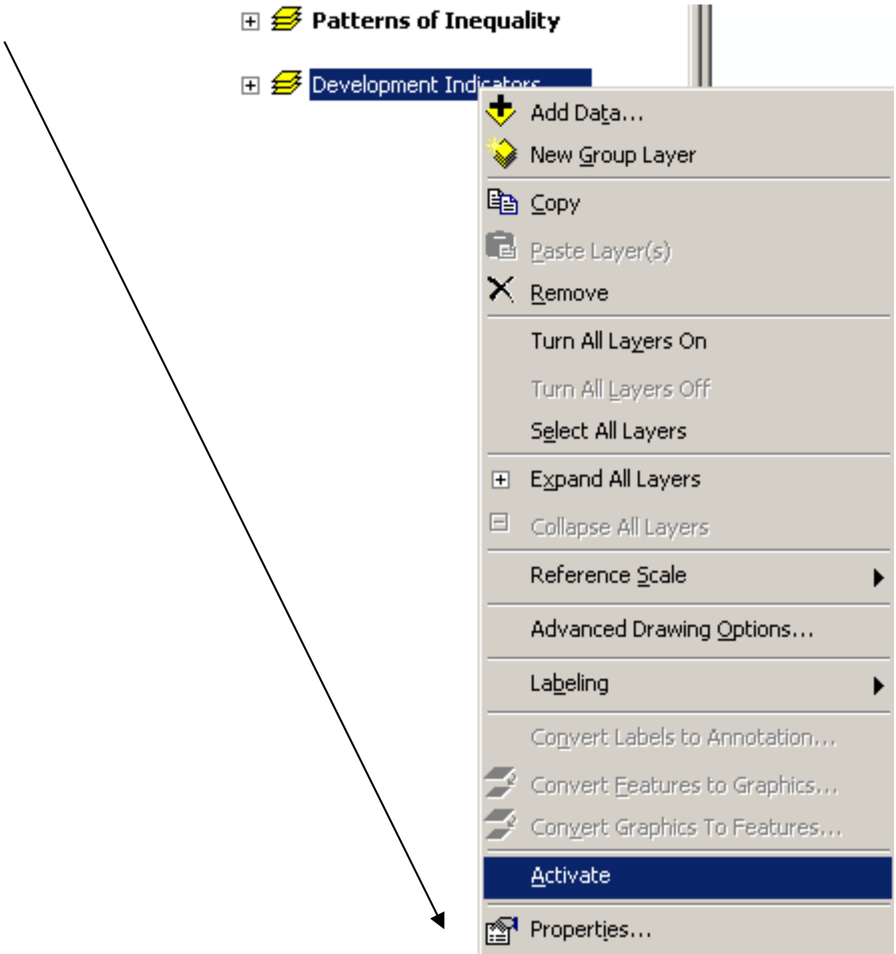
____

____

____

Click the Zoom to Full Extent button 

5 – RIGHT CLICK the data frame called **Development Indicators** and click **Activate**



6 – Use the following layers to answer the questions in this section:

- **% GDP in SERVICES**
- **% GDP in AGRICULTURE**
- **% GDP in INDUSTRY**

ACTIVITY – Complete the questions below.

a) ***Describe the pattern of SERVICES shown on the map***

b) ***Describe the pattern of AGRICULTURE shown on the map***

c) ***Describe the pattern of INDUSTRY shown on the map***

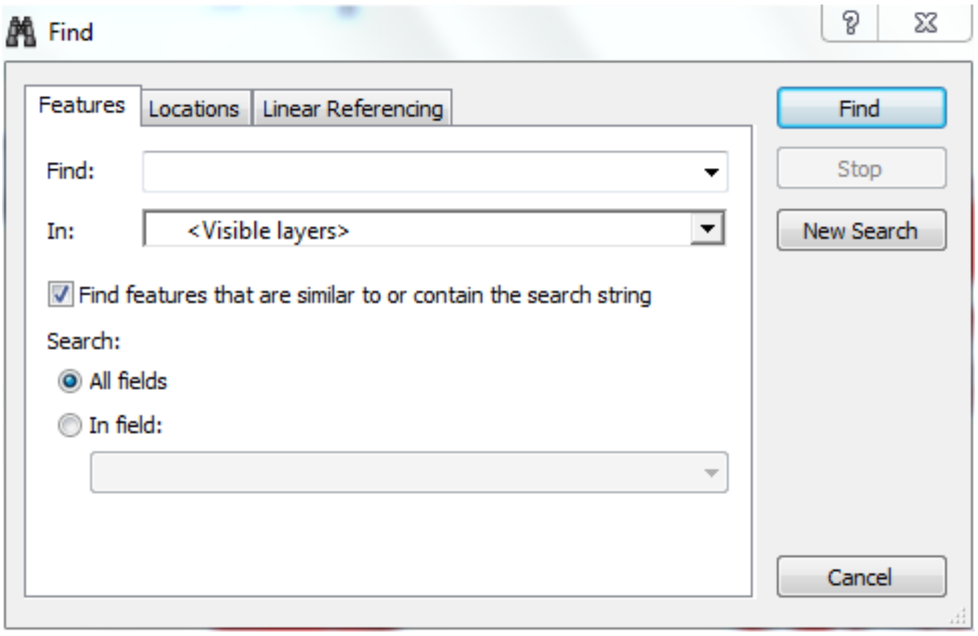
7 – Click the Zoom to Full Extent button  when you are finished.

Collapse and turn off the layers except for **% GDP in SERVICES** and **Countries**.

Now, you will explore the GDP contribution for some selected countries – Ecuador, Saudi Arabia, Australia, China, Ukraine and the Democratic Republic of Congo (DRC).

8 – Select the **Find** tool 

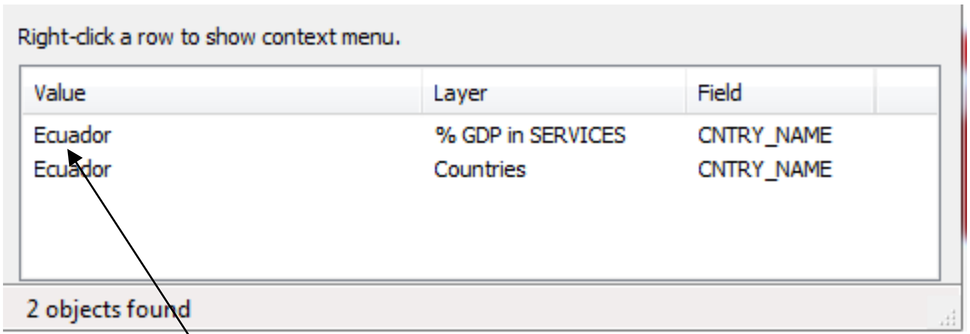
The following should appear.



Click the **Features** tab

Type in Ecuador in the Find field and click **Find**.

Ecuador should appear in a new area below the Find window as shown



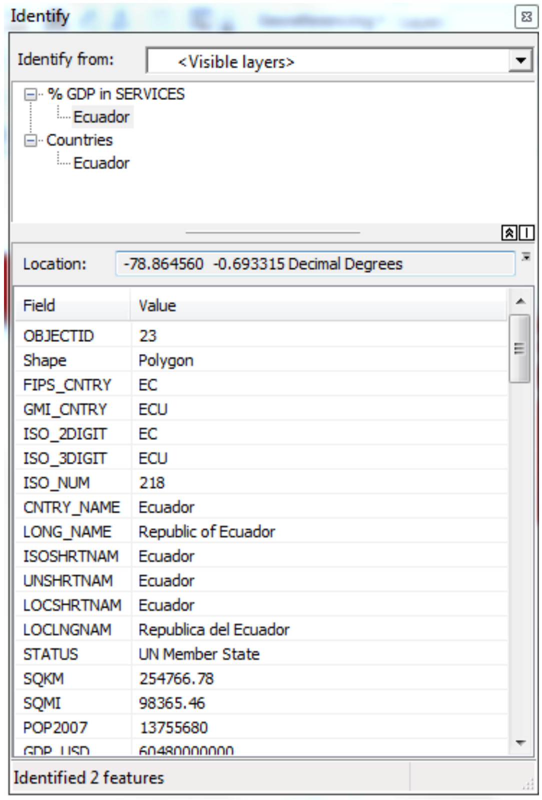
Click on Ecuador.

It should highlight on the map (NOTE: you may have to move the Find window so that Ecuador can be more easily seen).

When you have identified where Ecuador is located, close the Find window.

9 – Select the **Identify** button and click on Ecuador

The following should appear.



Scroll down to find the following information.

PGDP – AG

PGDP – IN

PGDP – SV

(NOTE: AG means Agriculture, IN means Industry, SV means Services)

a) ACTIVITY – In the space provided in the table below, record the % by contribution for each sector in Ecuador.

ECUADOR		**SAUDI ARABIA**		**AUSTRALIA**	
Sector	**%**	**Sector**	**%**	**Sector**	**%**
AGR		AGR	3.3	AGR	3.8
IND		IND	67	IND	26.2
SER		SER	29.8	SER	70

CHINA		UKRAINE		DRC	
Sector	**%**	**Sector**	**%**	**Sector**	**%**
AGR	11.9	AGR	17.7	AGR	55
IND	48.1	IND	42.7	IND	11
SER	40	SER	39.8	SER	34

b) ACTIVITY – Using this information, indicate (with a tick) whether you think the country is DEVELOPED or DEVELOPING.

COUNTRY	DEVELOPED?	DEVELOPING?
ECUADOR	☐	☐
SAUDI ARABIA	☐	☐
AUSTRALIA	☐	☐
CHINA	☐	☐
UKRAINE	☐	☐
DRC	☐	☐

10 – **Close** the **Identify** window. Turn OFF all layers (except **Countries**) and collapse them. Make sure you have zoomed to the full extent. 

Part C - APPLY

1 – Use the following layers to answer the questions in this section:

- **GDP per Capita**
- **Life Expectancy**
- **Literacy Rates**
- **Countries**

a) ACTIVITY – Explain the pattern of GDP around the world

____

____

____

____

b) ACTIVITY – Explain the pattern of life expectancy around the world

____

____

____

____

c) ACTIVITY – Is there a link between GDP per capita and Life Expectancy?

____

____

____

d) ACTIVITY – Is there a link between GDP per capita and Literacy Rates?

____

____

____

____

e) ACTIVITY – Describe any link that you can see between GDP per capita and Literacy Rates?

____

____

____

Part D - ANALYSE

1 – Use the following layers to answer the questions in this section:

- **GDP per Capita**
- **Human Development Index 1975**
- **Human Development Index 2006**

Select the **Swipe** tool to use in this part.

a) In 1975, where was there HIGH and LOW development?

b) In 2006, where was there HIGH and LOW development?

c) ACTIVITY – Compare the changes in DEVELOPMENT between 1975 and 2006.

d) ACTIVITY – Can you suggest reasons for this?

e) ACTIVITY – Compare the relationship between GDP per capita and HDI 2006?

Part E - EVALUATE

Look at the picture below and respond to the question in the space provided.

A wealthy western company has offered to provide funding to help improve standards of living for people living in an African village. The village is typical of those in many African countries with limited access to the most basic needs including food, clean water and medicine. The company would like its funding to go towards the:

- ***Improvement of mobile phone networks***
- ***Funding for the building of schools***
- ***Medical supplies and drugs for immunisation***
- ***Purchase of computers for schools***
- ***Development of Tourist and safari parks***
- ***Investment in renewable technologies***
- ***Improvement of roads and cycle paths***
- ***Education programs about contraception***

You are an expert at the United Nations specialising in Development issues. It is your job to look carefully at the company's funding proposal and evaluate the strengths and weaknesses of the plan.

Write your response in the space provided below.

Part F - CREATE

As an expert in development issues employed at the United Nations, you are regularly called upon to provide advice about how to measure living standards around the world.

Recently, there has been significant criticism of the 'HUMAN DEVELOPMENT INDEX' with many people now suggesting that it is no longer the best means of measuring development.

As a result, you have been asked by the Secretary-General of the United Nations to develop a different index to measure the quality of life of people living around the world.

You need to:

- ***d) Create a new name for the index***
- ***e) Outline the criteria that the index is based upon***
- ***f) Explain why it is a better measure of human development than the HDI***

Record your responses in the space provided below.

____

____

____

____

____

____

____

____

____

____

____

Direct Instruction

ENERGY

GIS Activity

Year 9

NAME: ______________________________________

GROUP: ______________________

DATE OF BIRTH: ___________________________

Part A

a) ACTIVITY – Define the following terms

Renewable Resource

____

____

Non-Renewable Resource

____

____

Sustainable

____

____

b) ACTIVITY – What does 'sustainable resource use' mean?

____

____

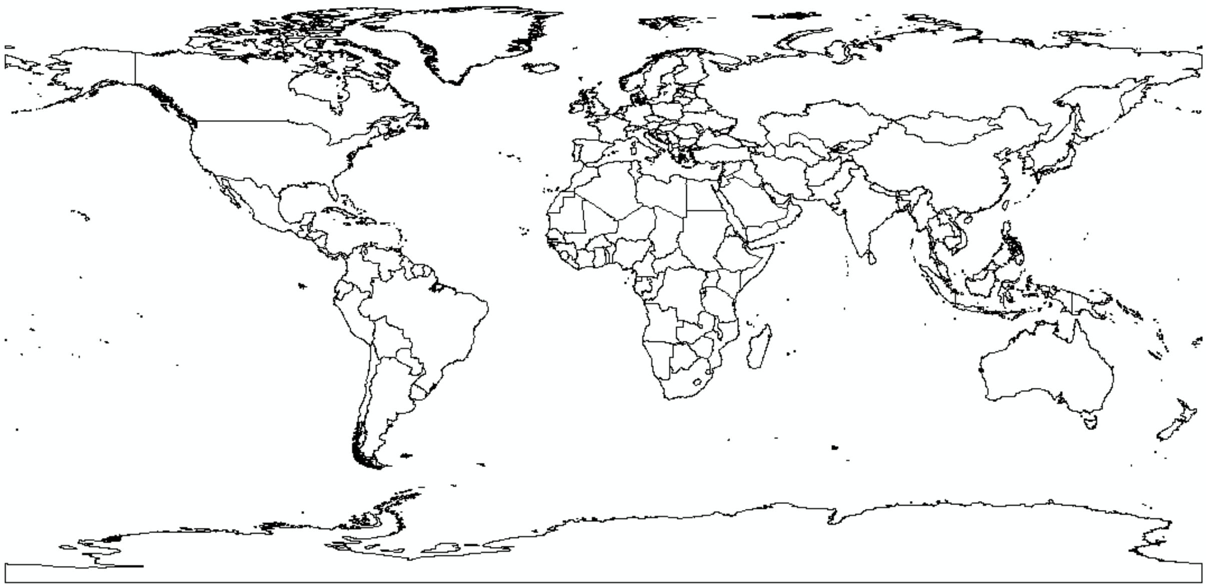
____

____

____

Part B

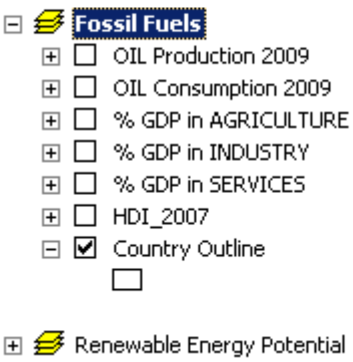
1 – The following should be displayed in **ArcMap**.



The left-hand side of the screen shows TWO **Data Frames**. They are called:

- **Fossil Fuels**
- **Renewable Energy Potential**

Expand **Fossil Fuels** by clicking the plus sign (+). The following should appear



The ACTIVE data frame is **Fossil Fuels** and the **Country Outline** data layer should be turned ON. Each of the layers listed highlights information relevant to Fossil Fuels around the world.

2 – Use the Zoom In and Zoom Out buttons  to explore the data by left clicking on the mouse and dragging a square over an area of interest.

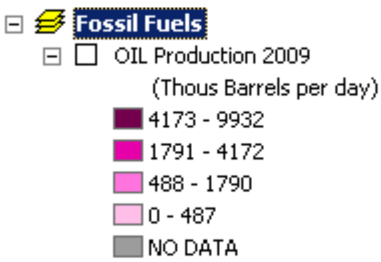
By clicking the + sign next to each of the layers, you can see that they can be turned ON and OFF.

3 – Click the **Zoom to Full Extent** button .

Make sure the **Countries** data layer is the only data layer turned ON.

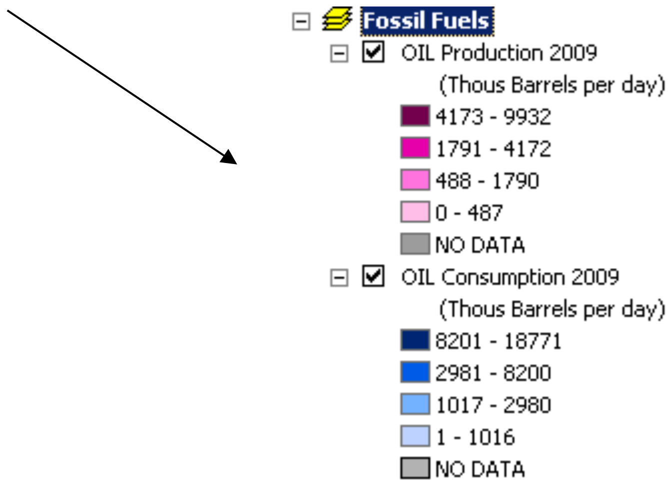
4 – Now you will examine the data relating to **Fossil Fuels**

Turn ON the data layer **Oil Production 2009** and expand it by clicking the plus sign (+) next to it.



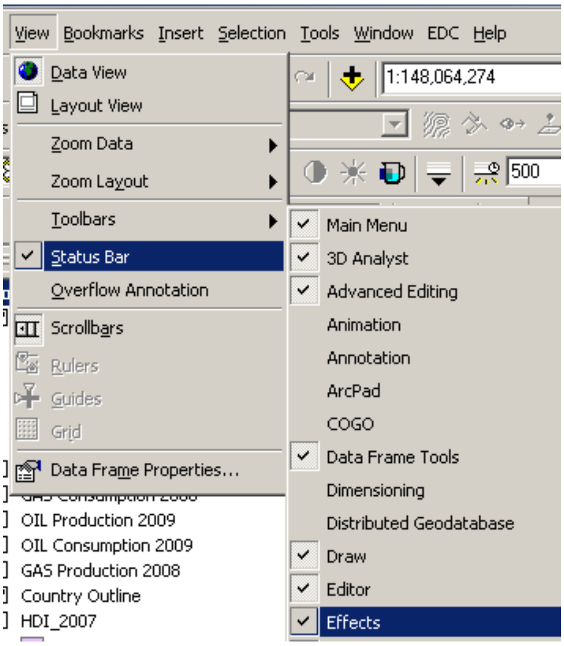
Expand the **Oil Consumption** layer by clicking on the plus sign (+) next to the layer title and turn it ON

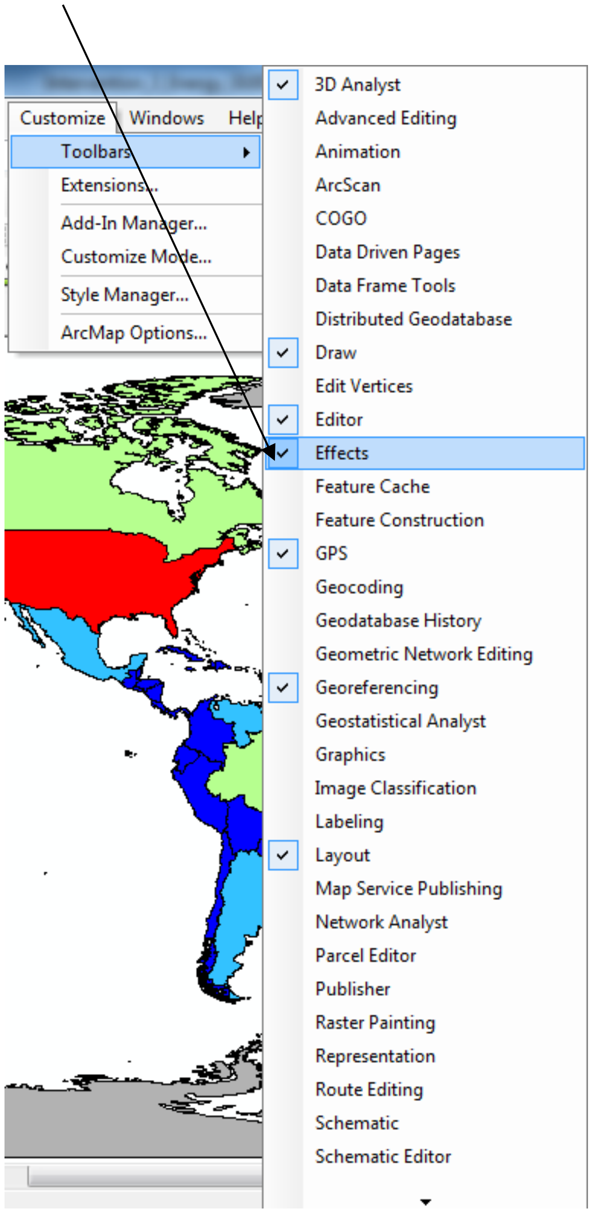
Your data layers should appear as follows



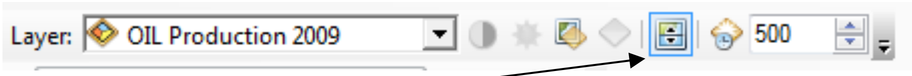
5 – From the **Customise** menu, select **Toolbars**

From the **Toolbars** that appear click on **Effects**





6 – In the **Effects** dropdown menu make sure that **Oil Production 2009** is selected



Select the **Swipe** button 

Click and hold your mouse cursor on the top of the map and drag it down the screen.

a) ACTIVITY – Describe the patterns of Oil Production and Consumption around the world.

7 – Turn OFF and collapse both **Oil Production 2009** and **Oil Consumption 2009.**

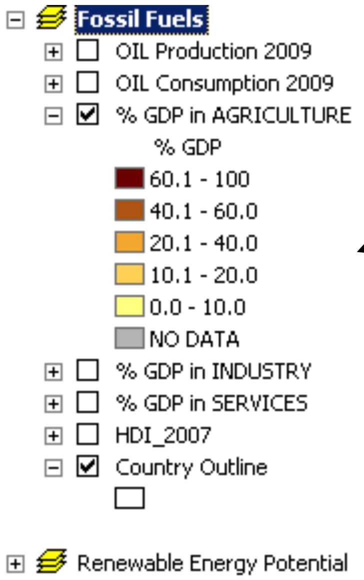
8 – Make sure that **Country Outline** is still turned ON and expanded.

Click the Zoom to Full Extent button 

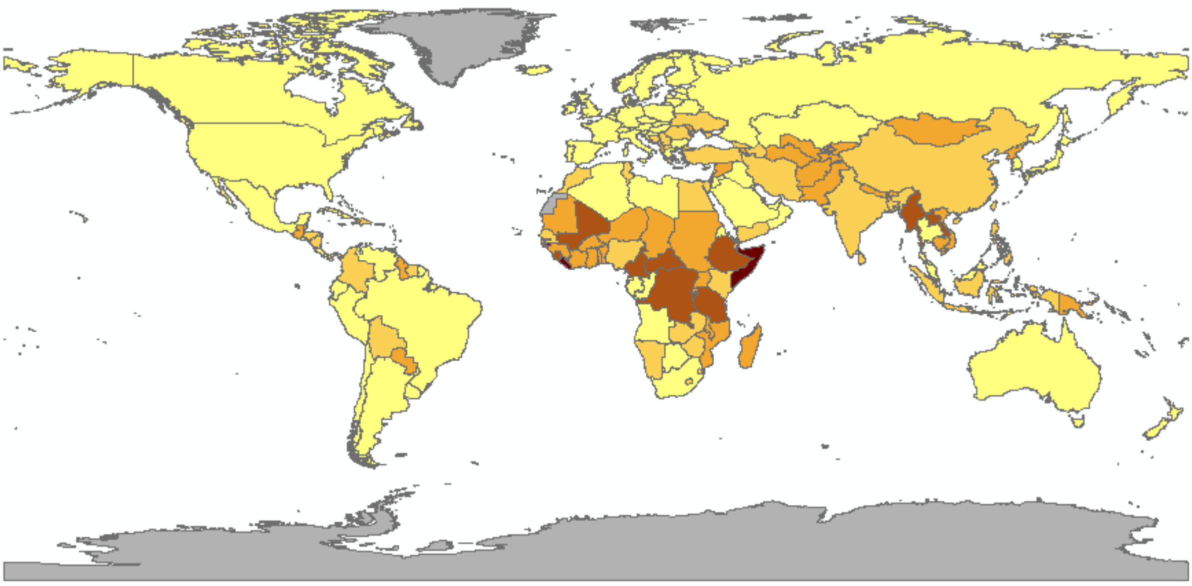
Part C

You are still using **Fossil Fuels** for Part C.

1 – Turn ON and expand the data layer **% GDP in AGRICULTURE**



Your map should appear as follows



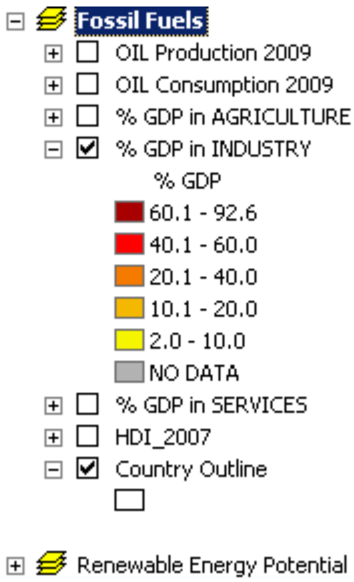
This is a world map which shows a country's contribution to GDP (%) from **AGRICULTURE**.

a) ACTIVITY – What does it mean if a country has a large % of its GDP generated by AGRICULTURE?

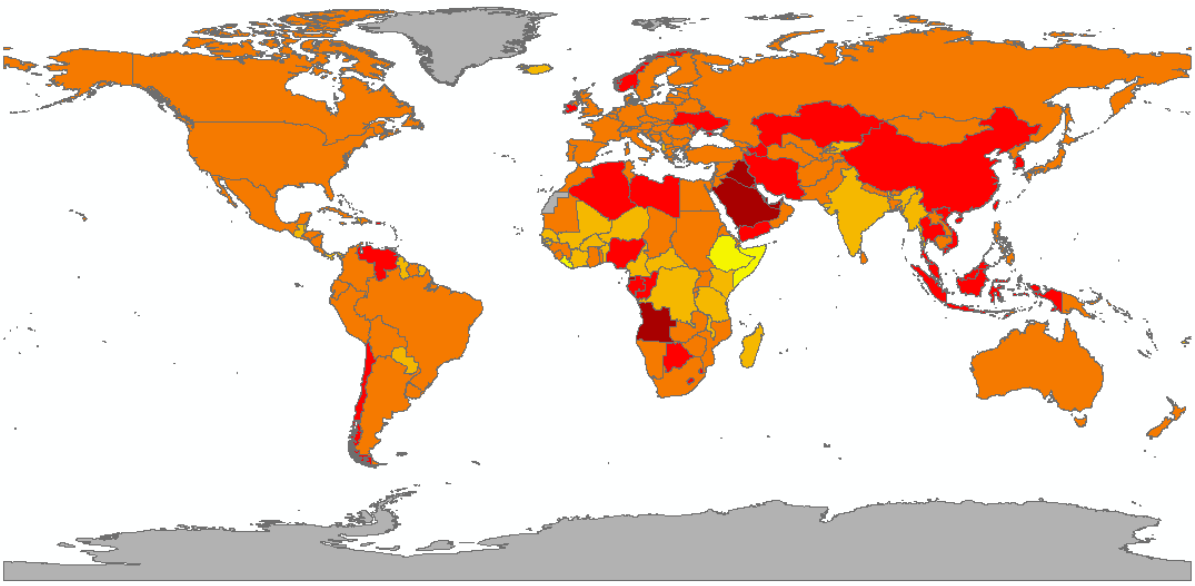
____

____

2 – Turn ON and expand the data layer **% GDP in INDUSTRY**



Your map should appear as follows



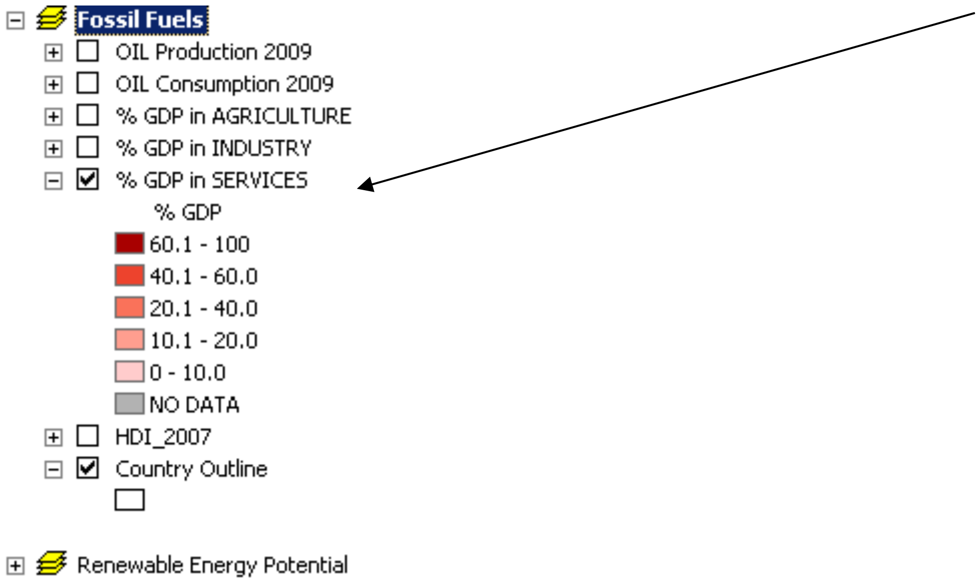
This is a world map which shows a country's contribution to GDP (%) from **INDUSTRY**.

a) ACTIVITY – What does it mean if a country has a large % of its GDP generated by INDUSTRY?

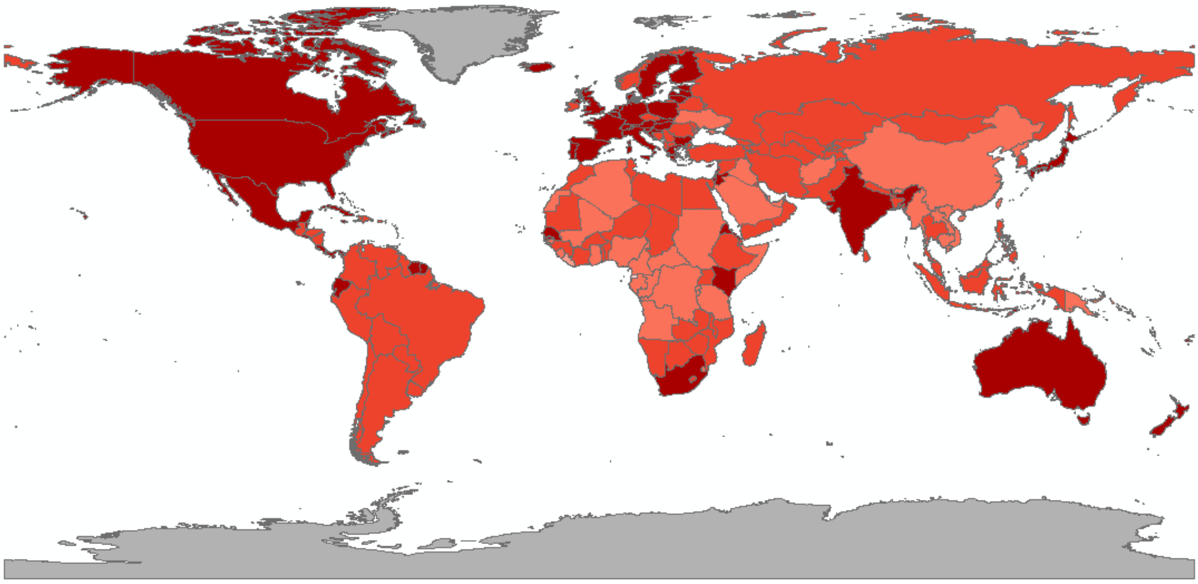
____

____

3 – Turn ON and expand the data layer **% GDP in SERVICES**



Your map should appear as follows



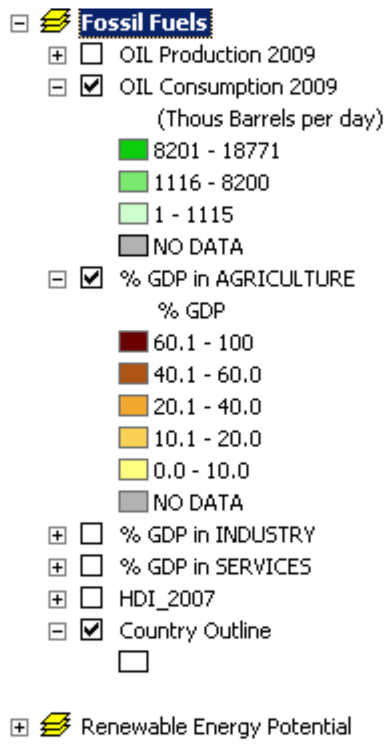
This is a world map which shows a country's contribution to GDP (%) from **SERVICES**.

a) ACTIVITY – What does it mean if a country has a large % of its GDP generated by SERVICES?

4 – Now, turn OFF **% GDP in SERVICES** and collapse it by clicking the minus (-)

Turn ON **% GDP in AGRICULTURE** and expand it

Turn ON and expand **Oil Consumption 2009**



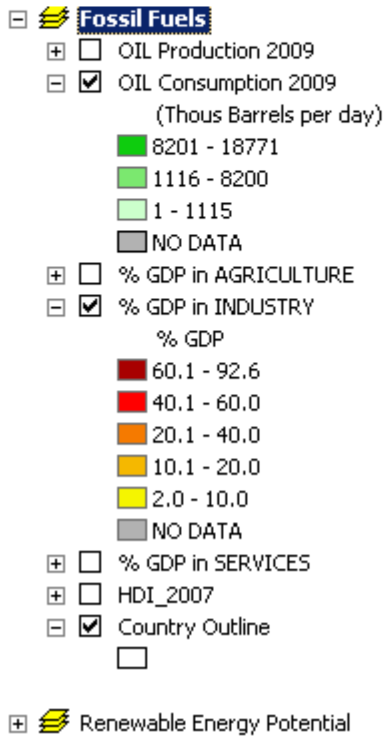
Use the **Flicker** tool  to compare these two layers. Remember to ensure that **Oil Consumption 2009** is selected in the **Effects** dropdown menu

a) ACTIVITY – Is there any connection between countries with high AGRICULTURE based GDP's and Oil Consumption? Suggestions reasons why.

5 – Keep **Oil Consumption 2009** turned ON and expanded

Turn OFF **% GDP in AGRICULTURE** and collapse it by clicking the minus (-)

Turn ON **% GDP in INDUSTRY** and expand it



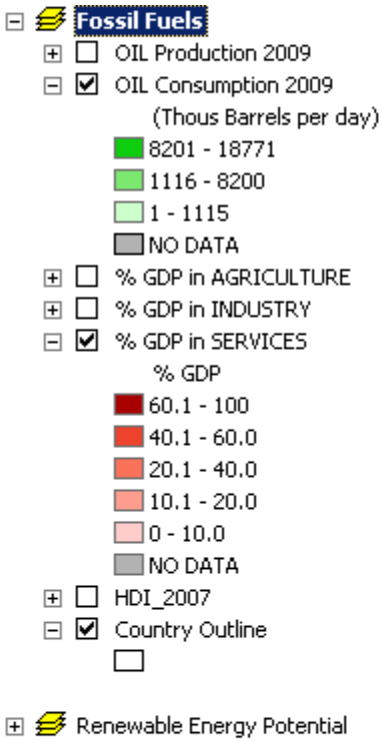
Use the **Flicker** tool to compare these two layers. Remember to ensure that **Oil Consumption 2009** is selected in the **Effects** dropdown menu

a) ACTIVITY – Is there any connection between countries with high INDUSTRY based GDP's and Oil Consumption? Suggestions reasons why.

6 – Keep **Oil Consumption 2009** turned ON and expanded

Turn OFF **% GDP in INDUSTRY** and collapse it by clicking the minus (-)

Turn ON **% GDP in SERVICES** and expand it



Use the **Flicker** tool to compare these two layers. Remember to ensure that **Oil Consumption 2009** is selected in the **Effects** dropdown menu

a) ACTIVITY – Is there any connection between countries with high SERVICES based GDP's and Oil Consumption? Suggestions reasons why.

____

____

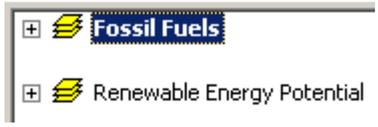
____

____

7 – Turn OFF **% GDP in SERVICES** and collapse it

Turn OFF **Oil Consumption 2009** and collapse it

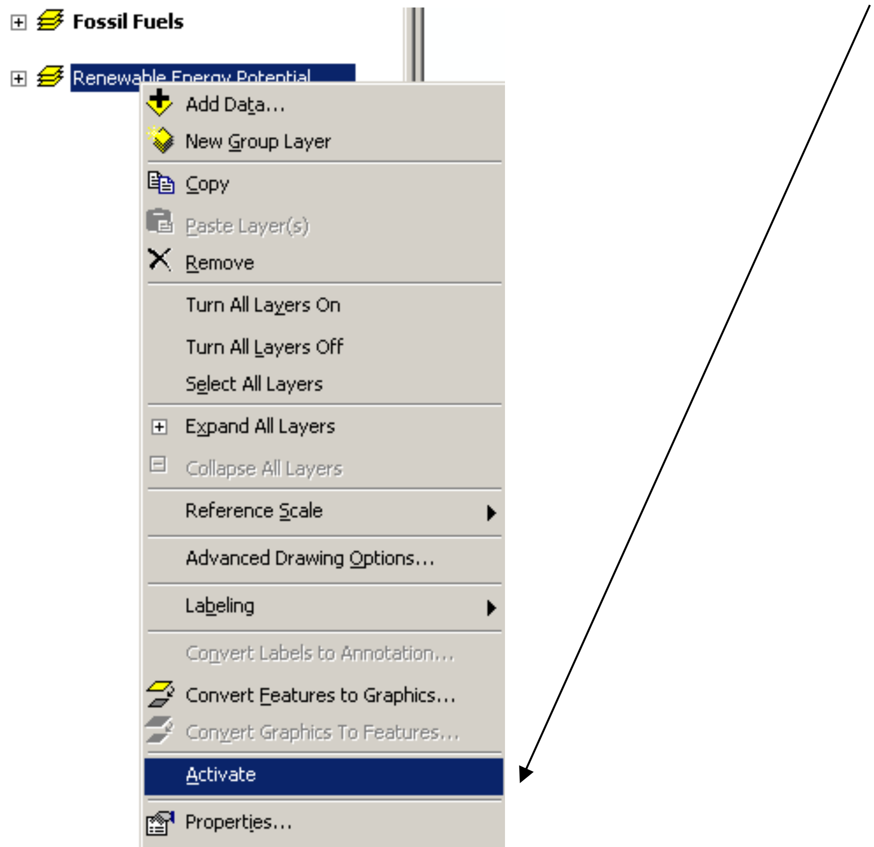
Collapse the **Fossil Fuels** Data Frame



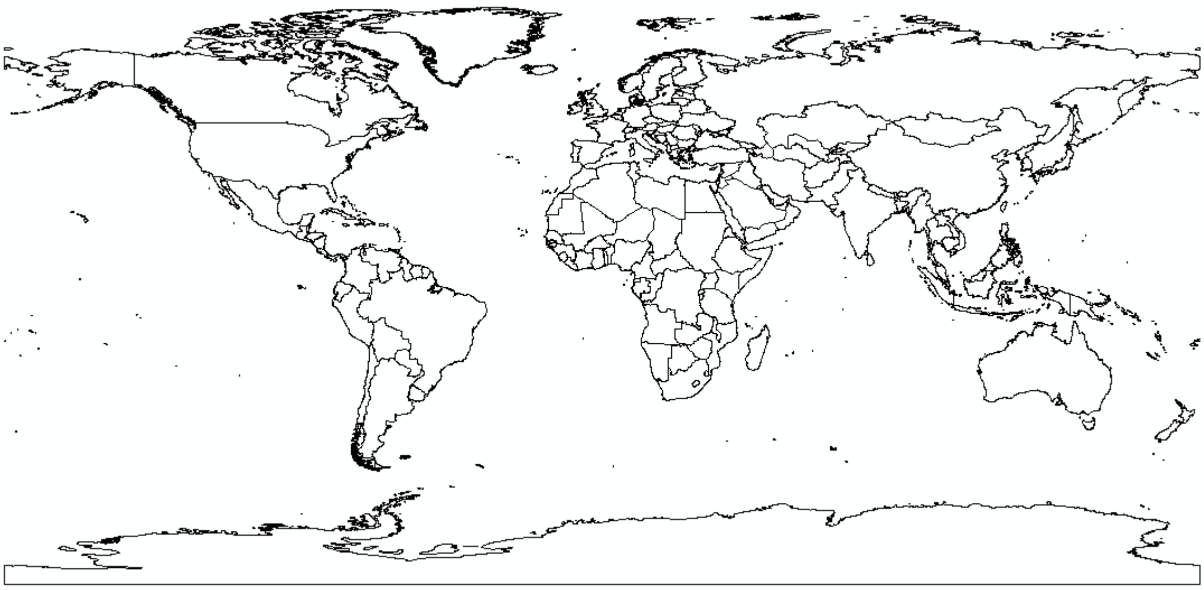
Make sure you have **Zoomed to the Full Extent** 

Part D

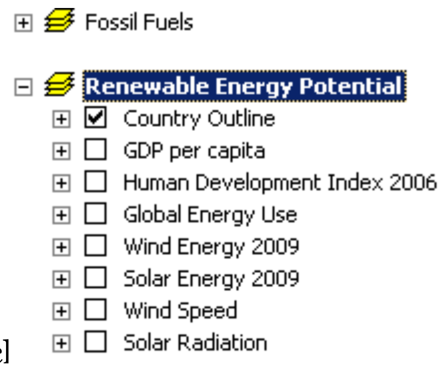
1 – Select **Renewable Energy Potential** and click **Activate**



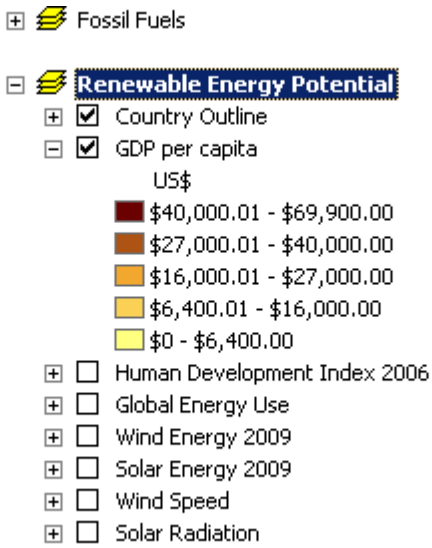
The following should appear.



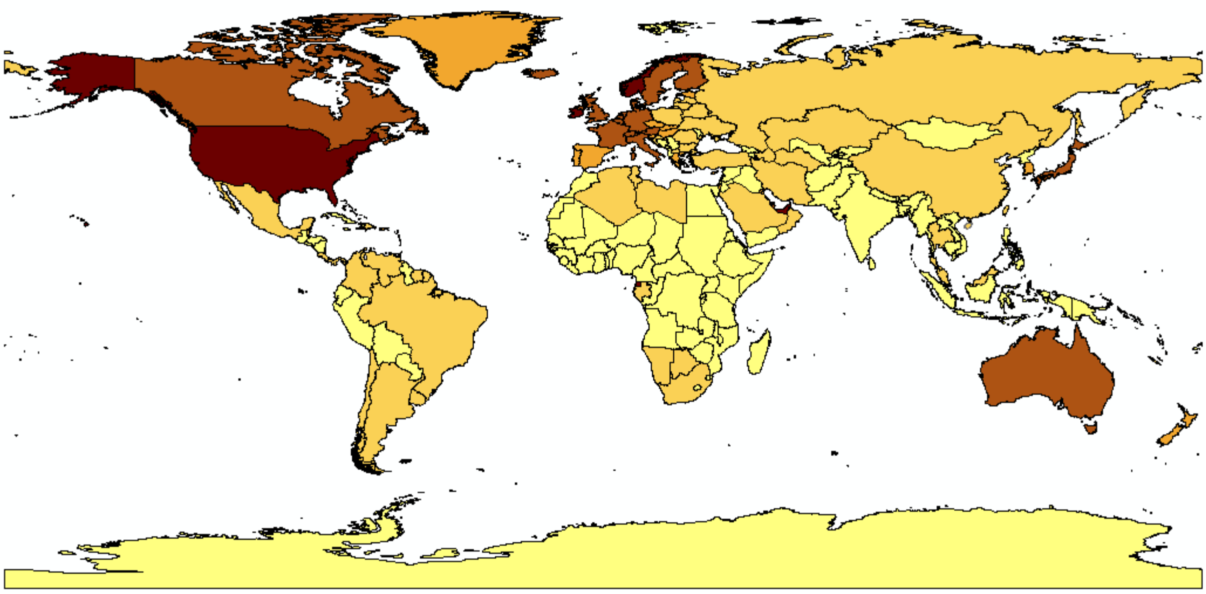
The layers to the left should appear as follows:



2 – Turn ON the **GDP per capita** layer and expand it by cl



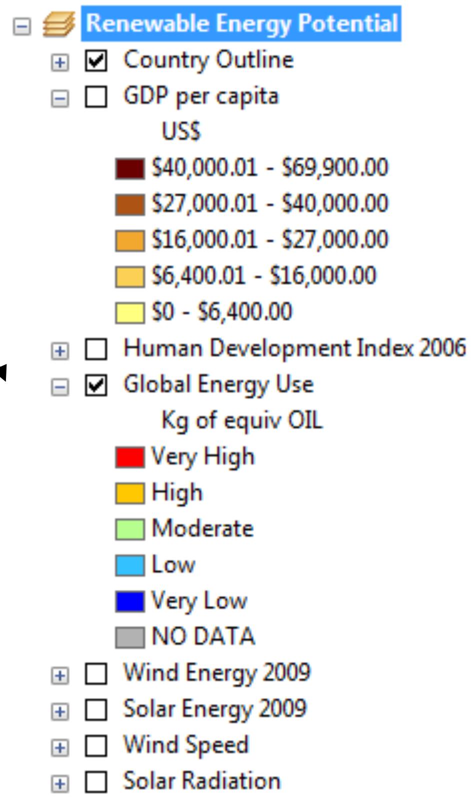
The following should appear.



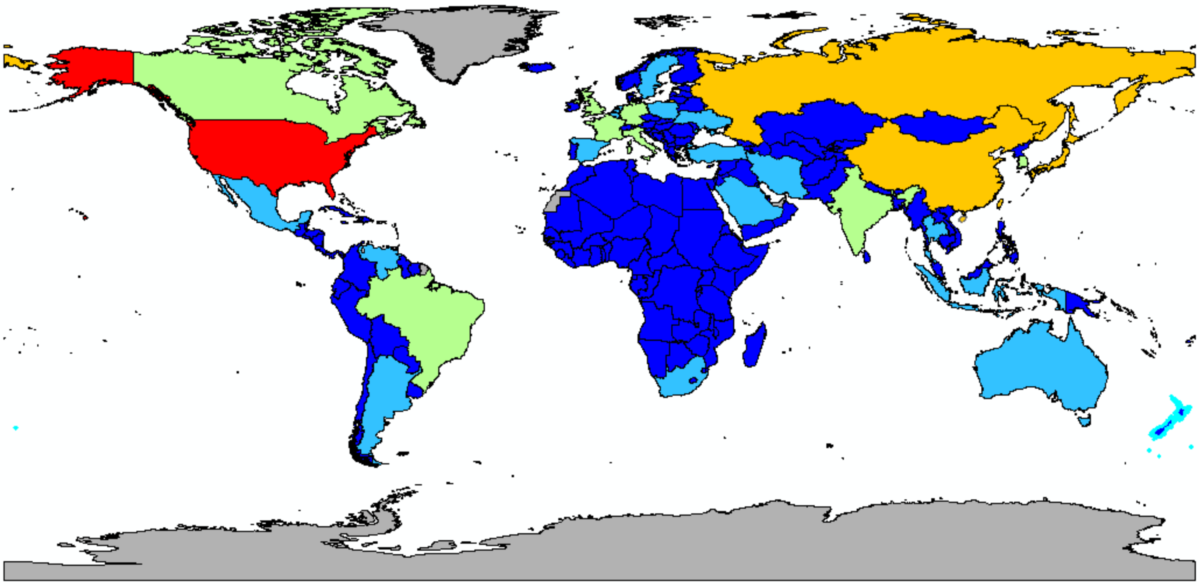
a) ACTIVITY – Describe the global pattern of GDP per capita

3 – Turn OFF the **GDP per Capita** layer but keep it expanded

Turn ON and expand the **Global Energy Use** layer.



The following should appear



a) ACTIVITY – Which areas of the world are the biggest users of Energy?

____

____

____

4 – Turn **GDP per Capita** back ON

Keep the **Global Energy** layer turned ON

Use the **Flicker** tool  to compare these two layers. Remember to ensure that **GDP per Capita** is selected in the **Effects** dropdown menu

a) Describe any patterns that you can see between GDP per capita and Global Energy Use?

____

____

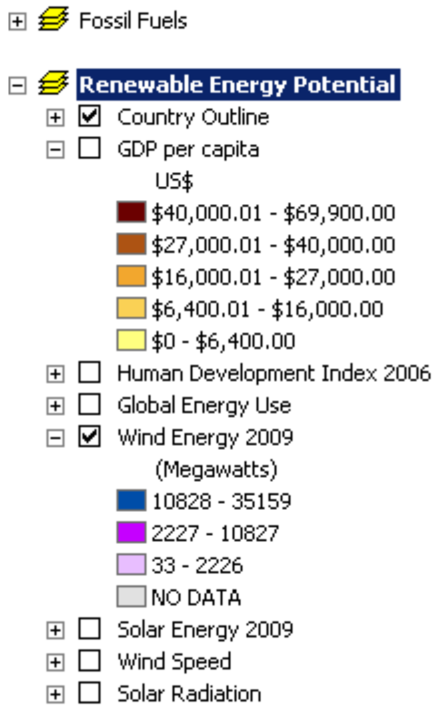
____

7 – Turn OFF the **GDP per Capita** layer but keep it expanded

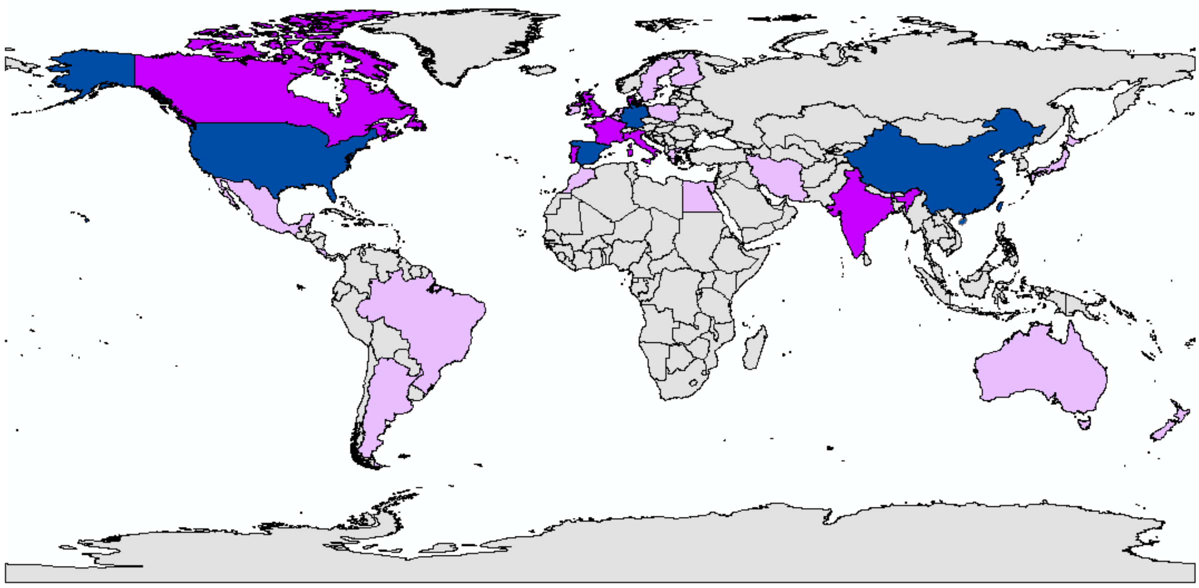
Turn OFF **Global Energy Use** and collapse it.

Expand the **Wind Energy 2009** layer and turn it ON.

The layers should appear as follows:



The following should appear



This layer shows those countries around the world that currently use GeoThermal power.

8 – Turn ON the **GDP per capita** layer and make sure it is expanded.

Use the **Flicker** tool to compare **GDP per Capita** and **Wind Energy 2009**. Remember to ensure that **GDP per Capita** is selected in the **Effects** dropdown menu

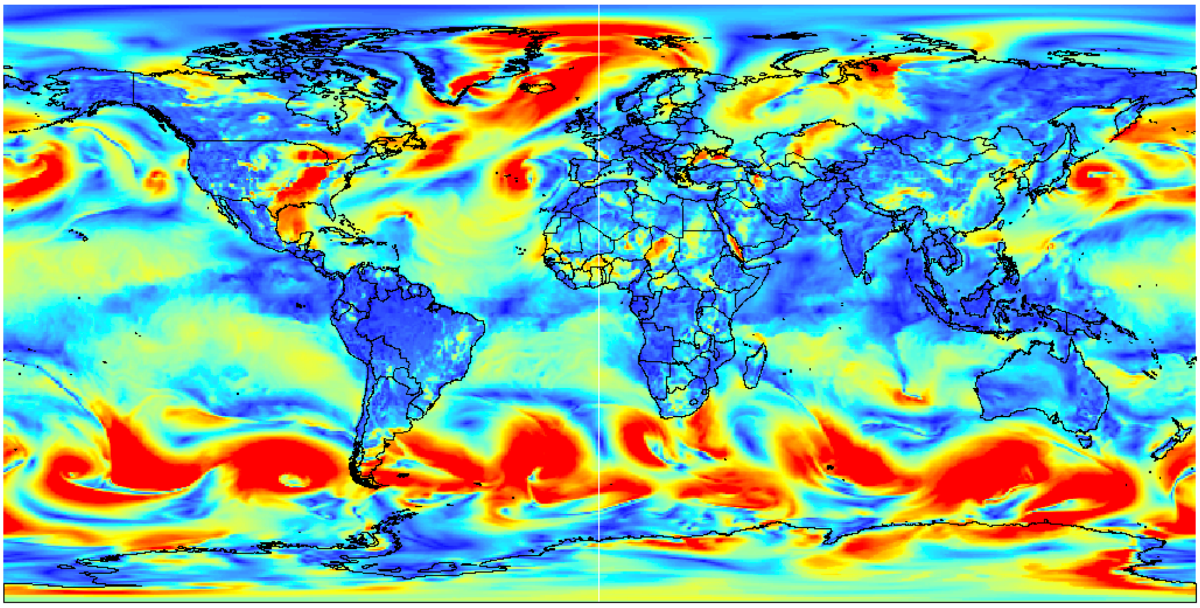
a) ACTIVITY – Is there any connection or link between GDP per Capita and the use of Wind Energy around the world? Explain.

9 – Keep the **GDP per capita** layer turned ON and make sure it is expanded.
Turn OFF and collapse the **Wind Energy 2009** layer
Turn ON and expand the **Solar Energy 2009** layer

Use the **Flicker** tool to compare **GDP per Capita** and **Solar Energy 2009**. Remember to ensure that **GDP per Capita** is selected in the **Effects** dropdown menu

a) ACTIVITY – Is there any connection or link between GDP per Capita and the use of Solar Energy around the world? Explain.

11 – Turn OFF and collapse all layers (except **Country Outlines**) and turn on the **Wind Speed** layer and expand it.



This layer shows where wind speeds are strong and weak around the globe.

Wind energy is a renewable energy source and one that is considered to be sustainable.

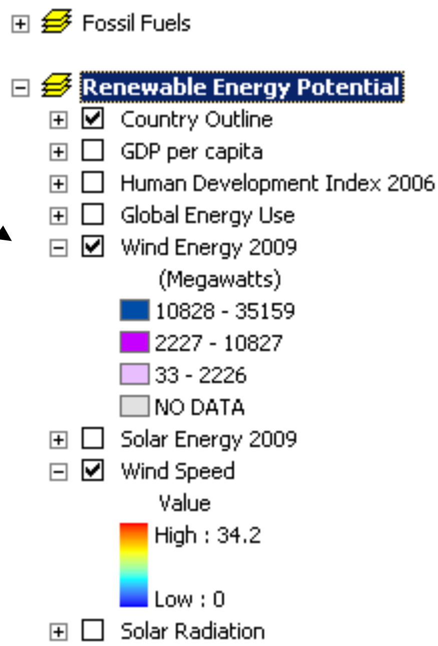
a) In general terms, describe the areas of the globe where wind speeds are at their greatest.

____

____

____

12 – Turn ON the **Wind Energy 2009** layer



From the **Effects** drop down menu, select **Wind Energy 2009**

Select the **Swipe** tool then click your mouse cursor on the left side of the screen and while holding down drag it across

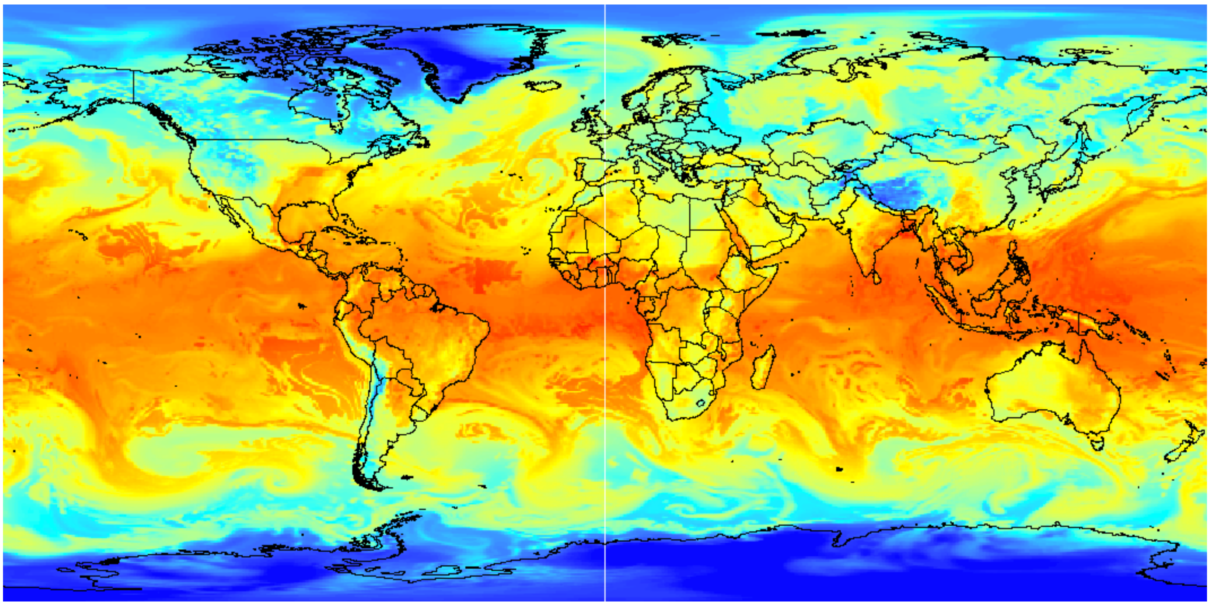
a) Is there any connection or pattern between countries who have adopted Wind Energy with the location of the world's strongest winds?

____

____

____

13 – Turn OFF and collapse all layers (except **Country Outlines**) and turn on the **Solar Radiation** layer and expand it.



This layer shows where solar radiation is the strongest and weakest around the globe. Solar energy is a renewable energy source and one that is considered to be sustainable.

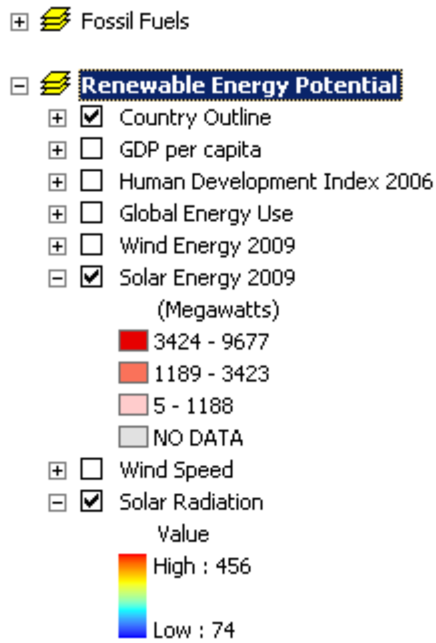
a) In general terms, describe the areas of the globe where solar radiation is at their greatest.

____

____

____

14 – Turn ON the **Solar Energy 2009** layer



From the **Effects** drop down menu, select **Solar Energy 2009**

Select the **Swipe** tool then click your mouse cursor on the left side of the screen and while holding down drag it across

a) Is there any connection or pattern between countries who have adopted Solar Energy and the strength of Solar Radiation?

____

____

____

b) Why do you think it is valuable for governments to know about the distribution of winds and solar radiation around the world?

____

____

____

Part E

Read the following and complete the activities below:

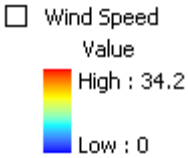
You are a scientist with the United Nations Energy Agency (UNEA) and your job is to identify non-fossil fuel sources that can be harnessed safely, cheaply and with minimal damage to the environment.

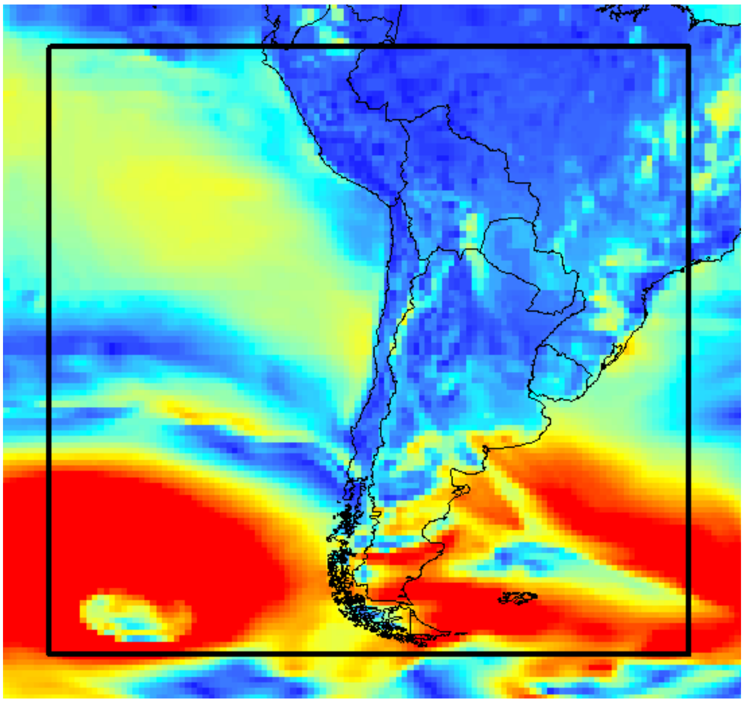
Recently, countries from different parts of the world have approached the UNEA for advice about developing renewable energy programs. These countries have formed an alliance to harness the potential of different renewable energy sources (either Solar or Wind). Each of the countries will benefit from the program being successful but the project cannot work without investment and money from a foreign company called 'SOLWIN'.

They need your advice about the best possible renewable energy solution for their country.

ACTIVITY – The maps following show a group of countries. The foreign company is proposing to invest in extensive Solar and Wind energy programs within the area shown. Your job is to determine whether the Solar and Wind energy programs are likely to be successful or not. Your evaluation of the project will determine whether or not the countries will allow SOLWIN to invest in their country.

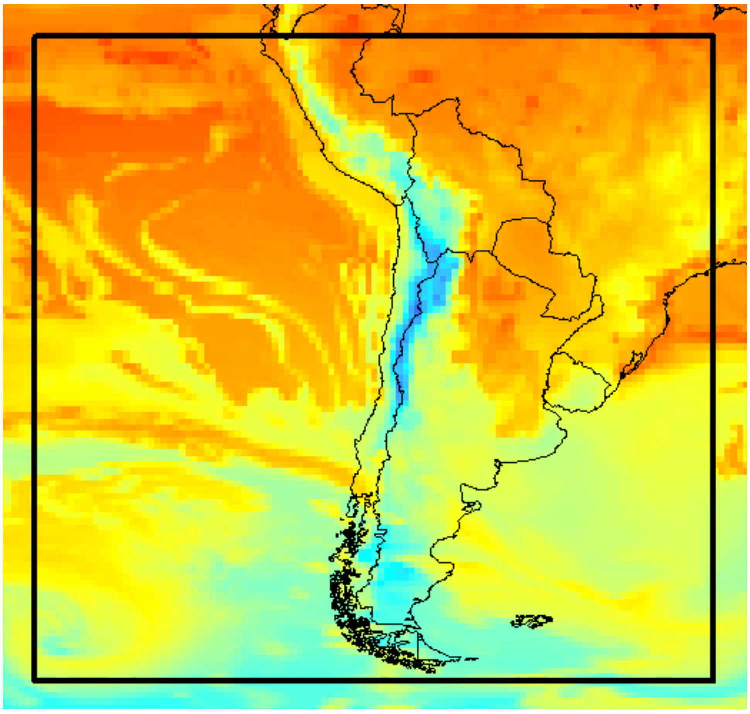
Group 1:

Wind Potential	



Your evaluation:

Solar Potential	☑ Solar Radiation Value High : 456 Low : 74



Your evaluation:

Part F

"The year is 2045 and the world is in trouble. The world's supply of fossil fuels is being rapidly depleted and as a result owners of motor vehicles must now pay A$5.00 per litre for petrol. Also, the cost of heating and cooling homes, businesses and schools has forced many public buildings to close because of their inability to pay for energy. Families and industry are suffering as well. Goods can't be transported across the country and many people must endure extreme heat during the summer and extreme cold during the winter because energy costs are so high. Add to this the effects of global warming as a result of climate change and there is a very serious situation on our hands. Alternative energy sources must be developed so that the world can have reliable, efficient, environmentally friendly ways to run their cars, power their manufacturing plants, and heat and cool their businesses, schools and homes."

ACTIVITY – Provide an outline for a new plan of 'Energy Use' that can be adopted by all countries to meet the needs of the world beyond 2045. Your plan needs to be flexible so that both Developed and Developing countries can maximise their adoption of potential energy sources.

ENERGY
GIS Activity
Year 9

NAME: ____

GROUP: ______________________

DATE OF BIRTH: ____________________________

Part A

a) ACTIVITY – Define the following terms

Renewable Resource

____

____

Non-Renewable Resource

____

____

Sustainable

____

____

b) ACTIVITY – What does 'sustainable resource use' mean?

____

____

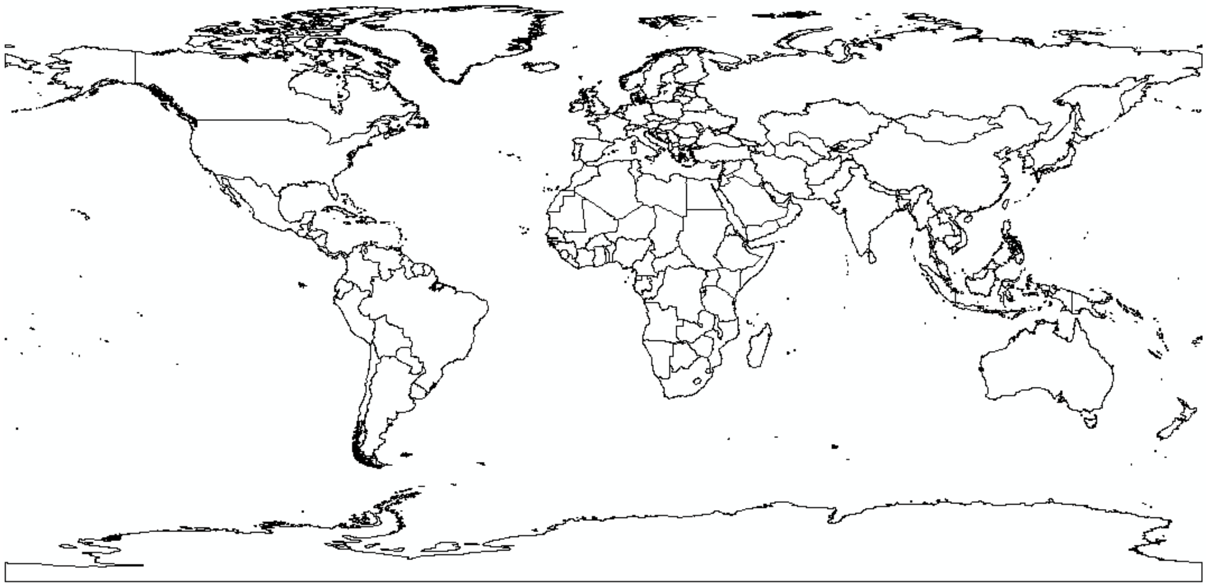
____

____

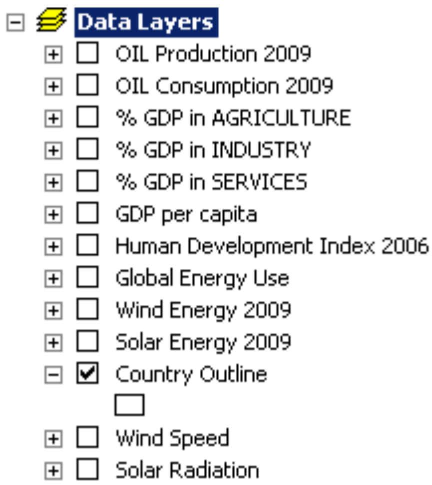
____

Part B

The following should be displayed in **ArcMap**.



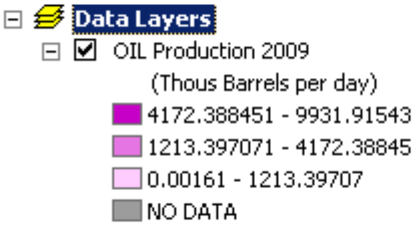
The left-hand side of the screen shows the **Data Layers** with different map layers within it.



How to view the map layers:

- The map layers can be turned on by checking or ticking the box as follows

- The map layer can also be expanded by clicking the plus sign (+)



- All the data displayed is relevant to the topic of **Energy.**
- You can explore the different map layers by turning the layers ON and OFF. You should also look at the using the Zoom In and Zoom Out buttons  to explore the data by left clicking on the mouse and dragging a square over an area of interest.

- Click the **Zoom to Full Extent** button .

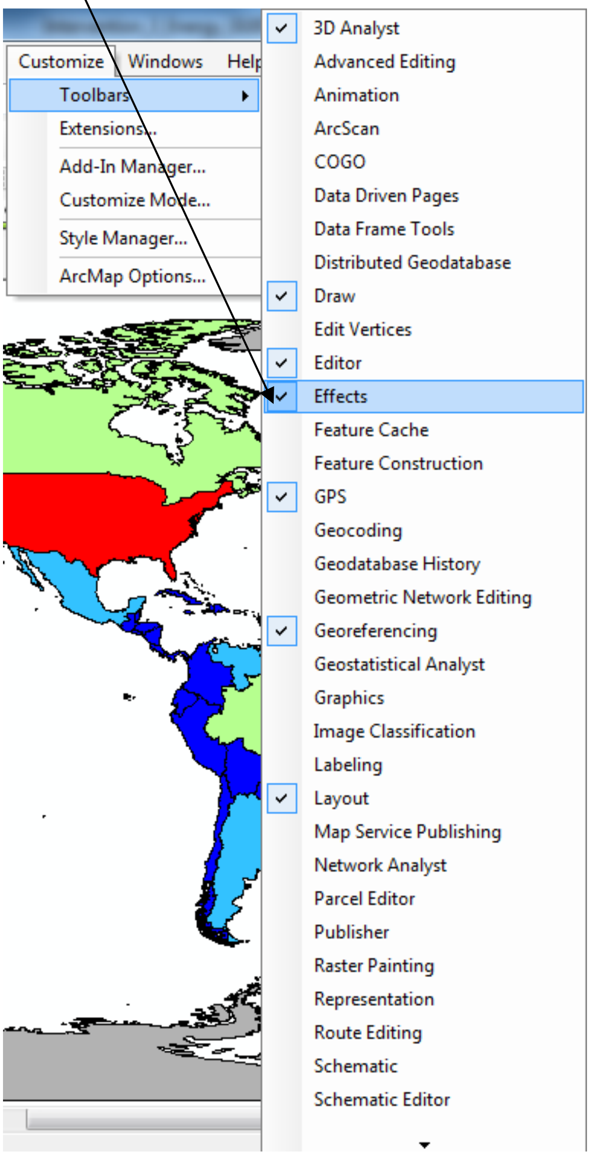
- Make sure the **Countries** data layer is the only data layer turned ON.

1 – Use the following layers to answer the questions in this section:

- **Oil Production 2009**
- **Oil Consumption 2009**
- **% GDP in AGRICULTURE**
- **% GDP in INDUSTRY**
- **% GDP in SERVICES**

From the **Customise** menu, select **Toolbars**

From the **Toolbars** that appear click on **Effects**



The **Effects** toolbar should appear. You may like to ‘dock’ it with the other toolbars at the top of ArcMap.

Turn **ON** the following layers

- **Oil Production**
- **Oil Consumption**

From the **Layer** dropdown menu, select **Oil Production** as shown

Select the **Swipe** button 

Click and hold the cursor at the top of the map and drag down the map. You should be able to see both **Oil Production** and **Oil Consumption** at the same time.

a) ACTIVITY – Describe the patterns of Oil Production and Consumption around the world.

____

____

____

____

Click the Zoom to Full Extent button 

Part C

1 – Use the following layers to answer the questions in this section:

- **% GDP in AGRICULTURE**
- **% GDP in INDUSTRY**
- **% GDP in SERVICES**

a) ACTIVITY – What does it mean if a country has a large % of its GDP generated by AGRICULTURE?

____

____

b) ACTIVITY – What does it mean if a country has a large % of its GDP generated by INDUSTRY?

____

____

c) ACTIVITY – What does it mean if a country has a large % of its GDP generated by SERVICES?

____

____

2 – Now you will use the following layers to answer questions in this section

- **Oil Production 2009**
- **Oil Consumption 2009**
- **% GDP in AGRICULTURE**
- **% GDP in INDUSTRY**
- **% GDP in SERVICES**

Turn ON **Oil Consumption 2009**

From the **Layer** dropdown menu, select **Oil Consumption** as shown

Select the **Flicker Layer** button 

Observe the differences in the layers as they turn on and off

Click the **Flicker Layer** button to stop the layers turning on and off

Compare **Oil Consumption 2009** AND **% GDP in AGRICULTURE**

a) ***ACTIVITY – Is there any connection between countries with high AGRICULTURE based GDP's and Oil Consumption? Suggestions reasons why.***

Compare **Oil Consumption 2009** AND **% GDP in INDUSTRY**

b) ***ACTIVITY – Is there any connection between countries with high INDUSTRY based GDP's and Oil Consumption? Suggestions reasons why.***

Compare **Oil Consumption 2009** AND **% GDP in SERVICES**

c) ***ACTIVITY – Is there any connection between countries with high SERVICES based GDP's and Oil Consumption? Suggestions reasons why.***

Make sure you have **Zoomed to the Full Extent** 

Part D

1 – Now you will use the following layers to answer questions in this section

- **GDP per Capita**
- **Human Development Index 2006**
- **Global Energy Use**
- **Wind Energy 2009**
- **Solar Energy 2009**
- **Wind Speed**
- **Solar Radiation**

a) ACTIVITY – Describe the global pattern of GDP per capita

____

____

____

____

Examine the following layer

- **Global Energy Use**

b) ACTIVITY – Which areas of the world are the biggest users of Energy?

____

____

____

Now, use the **Flicker Tool** to compare the following two layers

- **GDP per Capita**
- **Global Energy Use**

c) Describe any patterns that you can see between GDP per capita and Global Energy Use?

Now, use the **Flicker Tool** to compare the following two layers

- **Human Development Index 2006**
- **Global Energy Use**

d) Describe any patterns that you can see between Human Development Index 2006 and Global Energy Use?

Now, use the **Flicker Tool** to compare the following two layers

- **GDP per Capita**
- **Wind Energy 2009**

d) ACTIVITY – Is there any connection or link between GDP per Capita and the use of Wind Energy around the world? Explain.

Now, use the **Flicker Tool** to compare the following two layers

- **GDP per Capita**
- **Solar Energy 2009**

e) *ACTIVITY – Is there any connection or link between GDP per Capita and the use of Solar Energy around the world? Explain.*

____

____

____

____

Examine the following layer

- **Wind Speed**

f) *In general terms, describe the areas of the globe where wind speeds are at their greatest.*

____

____

____

Now, use the **Swipe Tool** to compare the following two layers

- **Wind Energy 2009**
- **Wind Speed**

g) *Is there any connection or pattern between countries who have adopted Wind Energy with the location of the world's strongest winds?*

____

Examine the following layer

- **Solar Radiation**

h) In general terms, describe the areas of the globe where solar radiation is at their greatest.

Now, use the **Swipe Tool** to compare the following two layers

- **Solar Energy 2009**
- **Solar Radiation**

i) Is there any connection or pattern between countries who have adopted Solar Energy and the strength of Solar Radiation?

j) Why do you think it is valuable for governments to know about the distribution of winds and solar radiation around the world?

Part E

Read the following and complete the activities below:

You are a scientist with the United Nations Energy Agency (UNEA) and your job is to identify non-fossil fuel sources that can be harnessed safely, cheaply and with minimal damage to the environment.

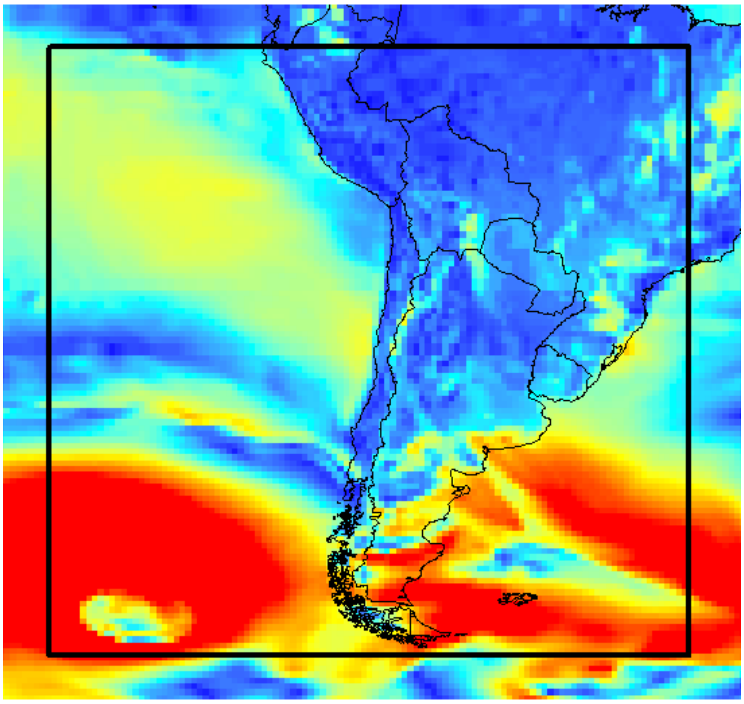
Recently, countries from different parts of the world have approached the UNEA for advice about developing renewable energy programs. These countries have formed an alliance to harness the potential of different renewable energy sources (either Solar or Wind). Each of the countries will benefit from the program being successful but the project cannot work without investment and money from a foreign company called 'SOLWIN'.

They need your advice about the best possible renewable energy solution for their country.

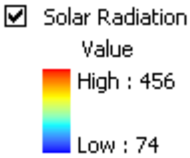
ACTIVITY – The maps following show a group of countries. The foreign company is proposing to invest in extensive Solar and Wind energy programs within the area shown. Your job is to determine whether the Solar and Wind energy programs are likely to be successful or not. Your evaluation of the project will determine whether or not the countries will allow SOLWIN to invest in their country.

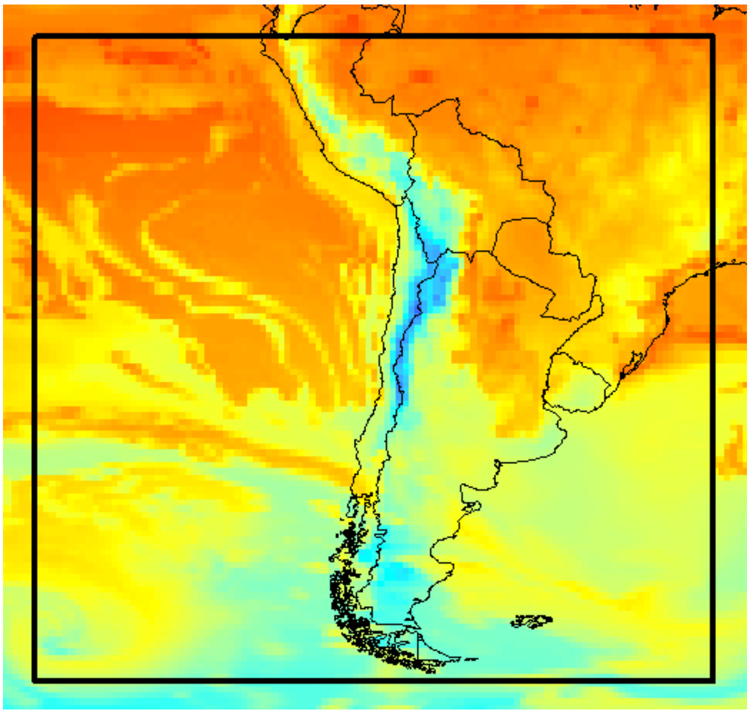
Group 1:

Wind Potential	Wind Speed Value High : 34.2 Low : 0



Your evaluation:

Solar Potential	



Your evaluation:

Part F

"The year is 2045 and the world is in trouble. The world's supply of fossil fuels is being rapidly depleted and as a result owners of motor vehicles must now pay A$5.00 per litre for petrol. Also, the cost of heating and cooling homes, businesses and schools has forced many public buildings to close because of their inability to pay for energy. Families and industry are suffering as well. Goods can't be transported across the country and many people must endure extreme heat during the summer and extreme cold during the winter because energy costs are so high. Add to this the effects of global warming as a result of climate change and there is a very serious situation on our hands. Alternative energy sources must be developed so that the world can have reliable, efficient, environmentally friendly ways to run their cars, power their manufacturing plants, and heat and cool their businesses, schools and homes."

ACTIVITY – Provide an outline for a new plan of 'Energy Use' that can be adopted by all countries to meet the needs of the world beyond 2045. Your plan needs to be flexible so that both Developed and Developing countries can maximise their adoption of potential energy sources.

Appendix B: Pre-tests and Post-tests

DEVELOPMENT

PRE-TEST

GIS Activity

Year 9

NAME: ____

GROUP: _________________________

DATE OF BIRTH: _______________________________

PRE-TEST

Part A

a) ACTIVITY – What do you understand the following terms to mean?

Development:

____

____

____

Global Inequality:

____

____

____

Wealth

____

____

____

Gross Domestic Product (GDP) per Capita

____

____

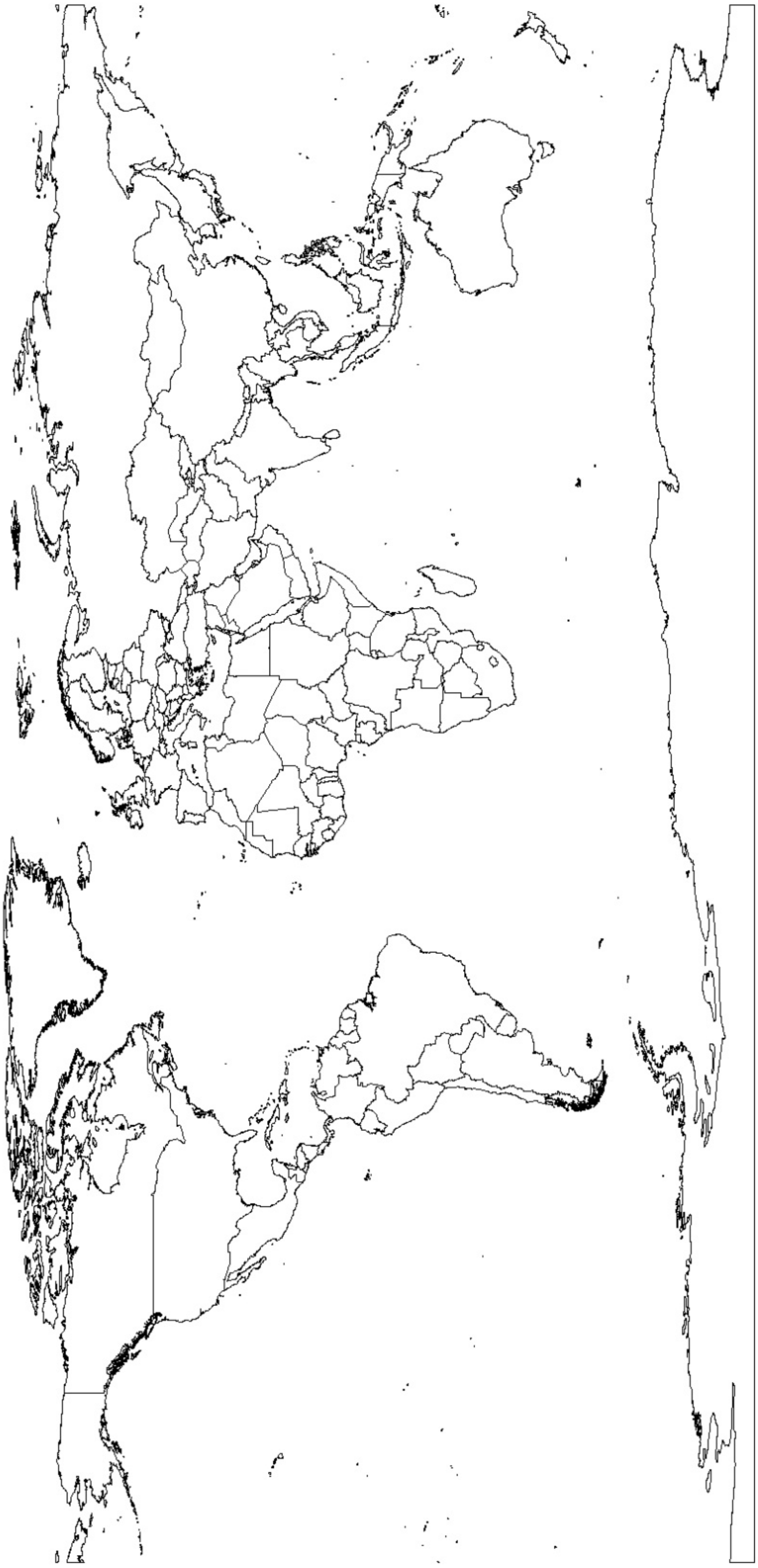
____

Part B

a) ACTIVITY – Examine the two photos below and comment on the differences.

b) ACTIVITY – Describe TWO things that could be used to determine a person's quality of life?

c) ACTIVITY – On the map below, indicate (by shading generally) those countries of the world that you understand to be the most economically advanced.



Part C

1 – MALNOURISHMENT DEFINITION: not having enough food to develop or function normally

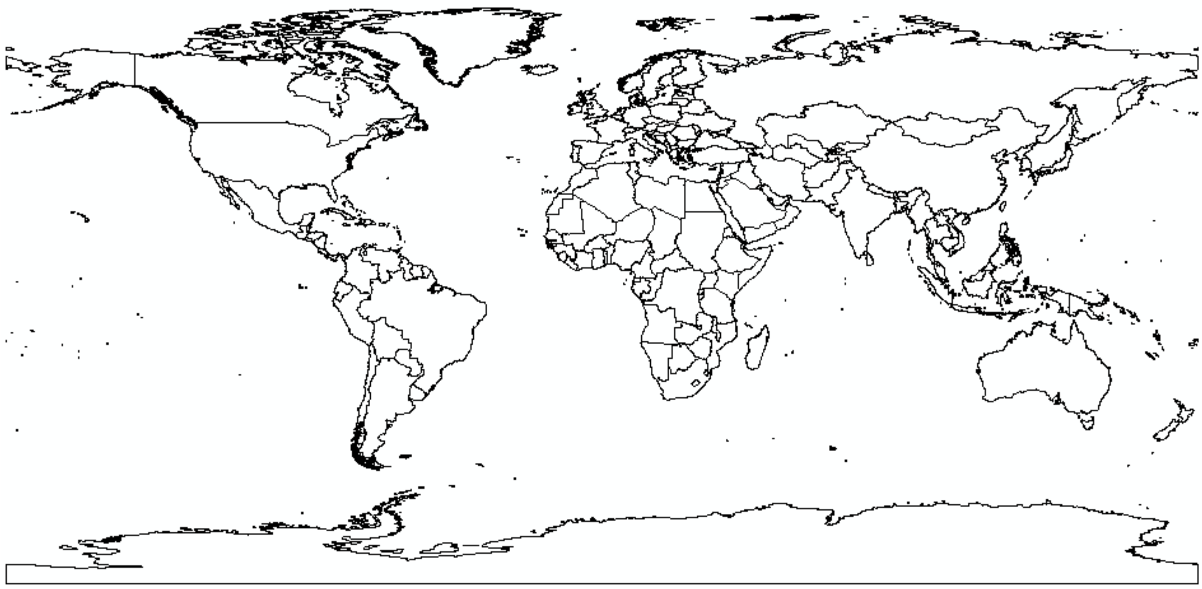
a) ACTIVITY – How could a world map showing patterns of child malnourishment be used to understand whether a country is developed or not?

____

____

____

2 – Using ArcMap, the following should be displayed



Explore the different map layers on the left-hand side by turning them ON and OFF. You should expand the layers also by clicking your mouse on the plus (+) sign.

Complete the following activities.

b) ***ACTIVITIES – Which map layers could be used to determine whether a country has a strong economy or not? Explain***

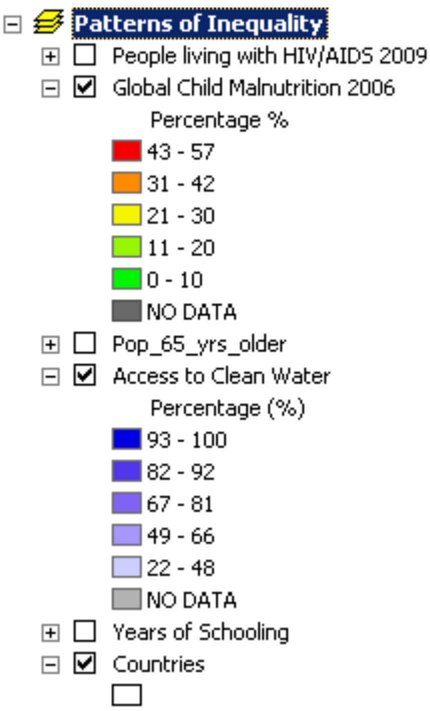
c) ***ACTIVITIES – Which map layers could be used to determine the standard of living for people living in the developing world? Explain***

Part D

1 – Click the **Zoom to Full Extent** button and make sure that the following map layers are expanded and turned ON (checked with a tick).

- **Global Child Malnutrition 2006**
- **Access to Clean Water**

The layers to left should look like this



2 – From the **Layer** dropdown menu, select **Global Child Malnutrition 2006**

Click on the **Swipe** tool

Click your mouse on the top of the screen and then drag the swipe tool down the screen. You should see the different layers.

a) ACTIVITY – Describe any patterns that you see between Global Malnutrition 2006 (%) AND Access to Clean Water

b) ACTIVITY – Explain reasons for any patterns that you see.

Part E

a) ACTIVITY – Imagine that you are a 15-year-old boy living in a poor village in a developing country. Identify THREE things that your family would most benefit from and explain how they would improve the quality of your family's life.

1 - ____

____

____

2 - ____

____

____

3 - ____

____

____

Part F

a) ACTIVITY – You work for one of the world's major Aid organisations. Your organisation was created to support and provide assistance to people living in the developing world.

Because of your understanding of developing countries, you have been asked by the Chairman of the Aid organisation to create a new strategy for improving the quality of life of people living in developing countries. Explain the strategy below.

Part G – Questionnaire

a) Complete the following questions by placing a ticking in the box that is most appropriate. The following scales apply.

Strongly Disagree	Mildly Disagree	Disagree	Neutral	Agree	Mildly Agree	Strongly Agree

PART A	Strongly Disagree	Mildly Disagree	Disagree	Neutral	Agree	Mildly Agree	Strongly Agree
1 – I feel that computers help me to do more interesting work in Geography	☐	☐	☐	☐	☐	☐	☐
2 – I feel confident using computers in my studies of Geography	☐	☐	☐	☐	☐	☐	☐
3 – I wish I had more chance to use computers in my studies of Geography	☐	☐	☐	☐	☐	☐	☐
4 – I wish my teacher used technology generally more in Geography classes	☐	☐	☐	☐	☐	☐	☐
5 – I feel that computers can help me to conduct effective research in Geography	☐	☐	☐	☐	☐	☐	☐

PART B	Strongly Disagree	Mildly Disagree	Disagree	Neutral	Agree	Mildly Agree	Strongly Agree
1 – I feel comfortable using technologies like GIS in Geography	☐	☐	☐	☐	☐	☐	☐
2 – I feel that GIS is a technology that can help me better understand maps in Geography	☐	☐	☐	☐	☐	☐	☐
3 – I feel that GIS is a technology that can help me better understand patterns in Geography	☐	☐	☐	☐	☐	☐	☐
4 – I enjoy investigating and exploring the Geographic data that is displayed in a GIS	☐	☐	☐	☐	☐	☐	☐
5 – I feel that a GIS is difficult to use and as a result it distracts me	☐	☐	☐	☐	☐	☐	☐

from the topic we are studying							

PART C	Strongly Disagree	Mildly Disagree	Disagree	Neutral	Agree	Mildly Agree	Strongly Agree
1 – I feel that I learn best in Geography when the teacher provides regular instructions during the lesson	☐	☐	☐	☐	☐	☐	☐
2 – I feel that I learn best in Geography when I work individually and on my own	☐	☐	☐	☐	☐	☐	☐
3 – I feel that I learn best in Geography when given work sheets with clear step-by-step instructions	☐	☐	☐	☐	☐	☐	☐
4 – I feel that I learn best in Geography when I am given a problem to solve or an issue to investigate	☐	☐	☐	☐	☐	☐	☐
5 – I feel that I learn best when I am given lots of resources and additional information during the lesson	☐	☐	☐	☐	☐	☐	☐

DEVELOPMENT

POST-TEST

GIS Activity

Year 9

NAME: ____________________________________

GROUP: _____________________

DATE OF BIRTH: __________________________

POST-TEST

Part A

a) ACTIVITY – What do you understand the following terms to mean?

Development:

Global Inequality:

Human Development Index

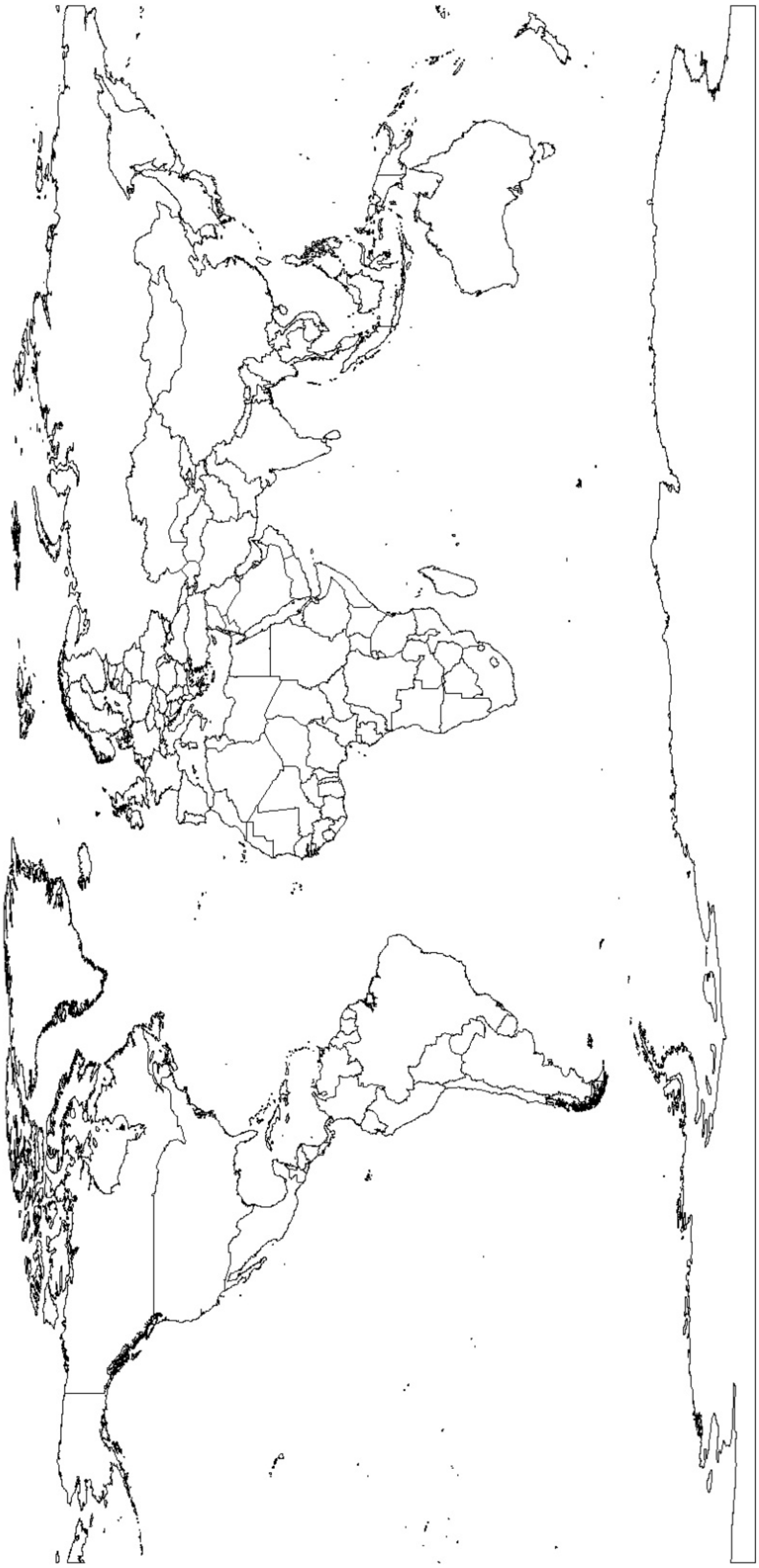
Poverty

Part B

a) ACTIVITY – Examine the two photos below and comment on the differences.


b) ACTIVITY – Describe TWO factors things that can cause inequalities in living standards

c) ***Activity – On the map below, indicate (by shading generally) those countries of the world that you understand to have the longest life expectancy***



Part C

1 – LITERACY DEFINITION: the ability to read and write

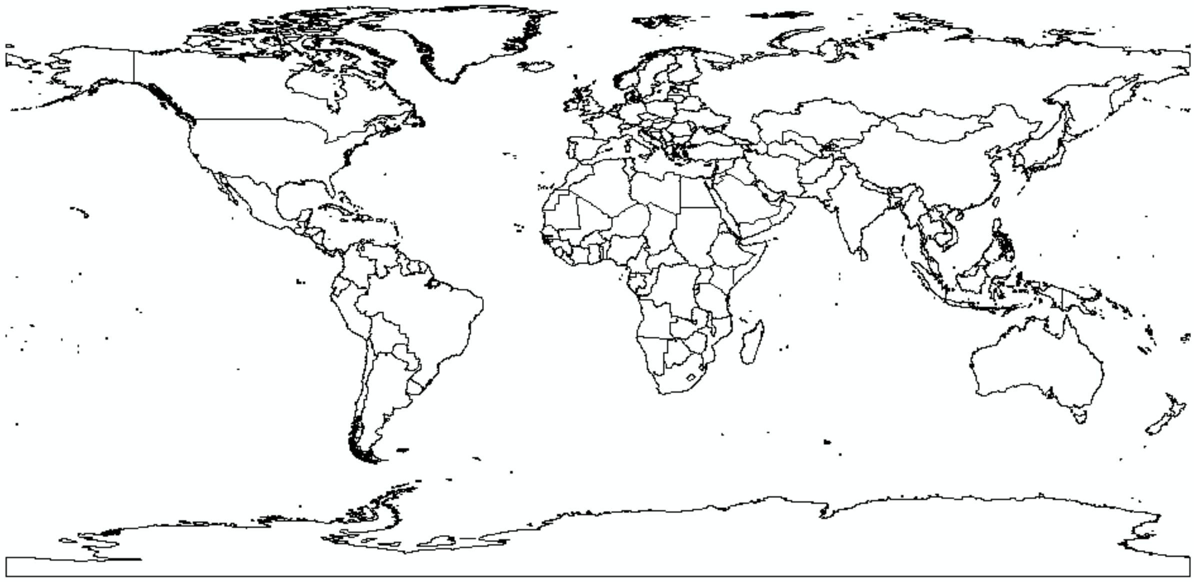
a) ACTIVITY – How could a map which shows literacy rates be used to understand whether a country is developed or not?

____

____

____

2 – Using ArcMap, the following should be displayed



Explore the different map layers on the left-hand side by turning them ON and OFF. You should expand the layers also by clicking your mouse on the plus (+) sign.

Complete the following activities.

a) ACTIVITY – Which map or maps could be used to determine whether a country has a good standard of health? Explain

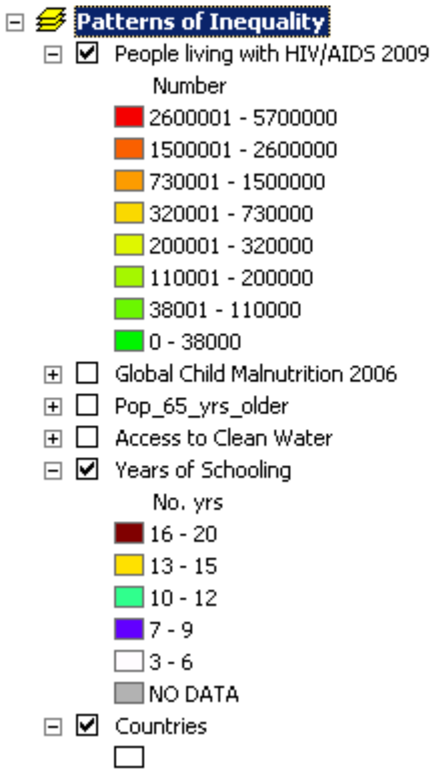
b) ACTIVITY – Which map or maps could be used to determine the quality of life for people living in the developing world? Explain

Part D

1 – Click the **Zoom to Full Extent** button  and make sure that the following map layers are expanded and turned ON (checked with a tick).

- **People living with HIV/AIDs 2009**
- **Years of Schooling**

The layers to left should look like this



2 – From the **Layer** dropdown menu, select **People living with HIV/AIDS 2009**

Click on the **Swipe** tool 

Click your mouse on the top of the screen and then drag the swipe tool down the screen. You should see the different layers.

a) ACTIVITY – Describe any patterns that you see between People living with HIV/AIDS (%) AND Yrs of Schooling (No. of yrs)

b) ACTIVITY – Explain reasons for any patterns that you see.

Part E

a) ACTIVITY – If you were a member of an Aid Organisation whose responsibility it was to help people in a developing country, explain THREE things that would you do to improve the standard of living for the people (in rank order)?

1 - ______________________________

____

____

2 - ______________________________

____

____

3 - ______________________________

____

____

Part F

a) ACTIVITY – You work for the United Nations and have an excellent knowledge and understanding of inequalities that exist between countries of the developed and developing world.

You have been asked to create a new index for determining whether a country is wealthy or poor.

Use your knowledge to create the new measure and explain the reasoning that you used to produce the index.

Part G – Questionnaire

a) Complete the following questions by placing a ticking in the box that is most appropriate. The following scales apply.

Strongly Disagree	Mildly Disagree	Disagree	Neutral	Agree	Mildly Agree	Strongly Agree

PART A	Strongly Disagree	Mildly Disagree	Disagree	Neutral	Agree	Mildly Agree	Strongly Agree
1 – I feel that computers help me to do more interesting work in Geography	☐	☐	☐	☐	☐	☐	☐
2 – I feel confident using computers in my studies of Geography	☐	☐	☐	☐	☐	☐	☐
3 – I wish I had more chance to use computers in my studies of Geography	☐	☐	☐	☐	☐	☐	☐
4 – I wish my teacher used technology generally more in Geography classes	☐	☐	☐	☐	☐	☐	☐
5 – I feel that computers can help me to conduct effective research in Geography	☐	☐	☐	☐	☐	☐	☐

PART B	Strongly Disagree	Mildly Disagree	Disagree	Neutral	Agree	Mildly Agree	Strongly Agree
1 – I feel comfortable using technologies like GIS in Geography	☐	☐	☐	☐	☐	☐	☐
2 – I feel that GIS is a technology that can help me better understand maps in Geography	☐	☐	☐	☐	☐	☐	☐
3 – I feel that GIS is a technology that can help me better understand patterns in Geography	☐	☐	☐	☐	☐	☐	☐
4 – I enjoy investigating and exploring the Geographic data that is displayed in a GIS	☐	☐	☐	☐	☐	☐	☐
5 – I feel that a GIS is difficult to use and as a result it distracts me from the topic we are studying	☐	☐	☐	☐	☐	☐	☐

PART C	Strongly Disagree	Mildly Disagree	Disagree	Neutral	Agree	Mildly Agree	Strongly Agree
1 – I feel that I learn best in Geography when the teacher	☐	☐	☐	☐	☐	☐	☐

provides regular instructions during the lesson							
2 – I feel that I learn best in Geography when I work individually and on my own	☐	☐	☐	☐	☐	☐	☐
3 – I feel that I learn best in Geography when given work sheets with clear step-by-step instructions	☐	☐	☐	☐	☐	☐	☐
4 – I feel that I learn best in Geography when I am given a problem to solve or an issue to investigate	☐	☐	☐	☐	☐	☐	☐
5 – I feel that I learn best when I am given lots of resources and additional information during the lesson	☐	☐	☐	☐	☐	☐	☐

PART D	**Strongly Disagree**	**Mildly Disagree**	**Disagree**	**Neutral**	**Agree**	**Mildly Agree**	**Strongly Agree**
1 – I felt that I was able to use information from the GIS to understand the patterns of inequality that exist in the world	☐	☐	☐	☐	☐	☐	☐
2 – I felt that I was able to apply information from the GIS to understand the topic of Development	☐	☐	☐	☐	☐	☐	☐
3 – I felt that I was able to analyse information in the GIS to understand differences between Development indicators	☐	☐	☐	☐	☐	☐	☐
4 – I felt that I was able to evaluate information from the GIS to come up with solutions to the problems of the Developing world	☐	☐	☐	☐	☐	☐	☐
5 – I found that the GIS helped me to think of other questions relating to the topic of Development	☐	☐	☐	☐	☐	☐	☐
6 – I found that the GIS increased my level of motivation to learn more about the topic of Development	☐	☐	☐	☐	☐	☐	☐
7 – I feel that the GIS helps me learn better than traditional resources such as worksheets and handouts	☐	☐	☐	☐	☐	☐	☐
8 – I felt that my understanding of Development improved due to the teacher alone	☐	☐	☐	☐	☐	☐	☐

PART E

a) What did you like about this lesson?

b) What didn't you like about this lesson?

c) Do you have any other comments about the lesson?

d) In your opinion, how do you think this lesson could have been improved to help you better understand the topic of **development**?

e) How do you think the GIS could have been used more effectively to help you understand the topic of **development** in this lesson?

ENERGY

PRE-TEST

GIS Activity

Year 9

NAME: ____

GROUP: ______________________

DATE OF BIRTH: ____________________________

PRE-TEST

Part A

a) ACTIVITY – What do you understand the following terms to mean?

Fossil Fuel

____

____

Renewable Energy

____

____

Sustainable Resource Use

____

____

Gross Domestic Product

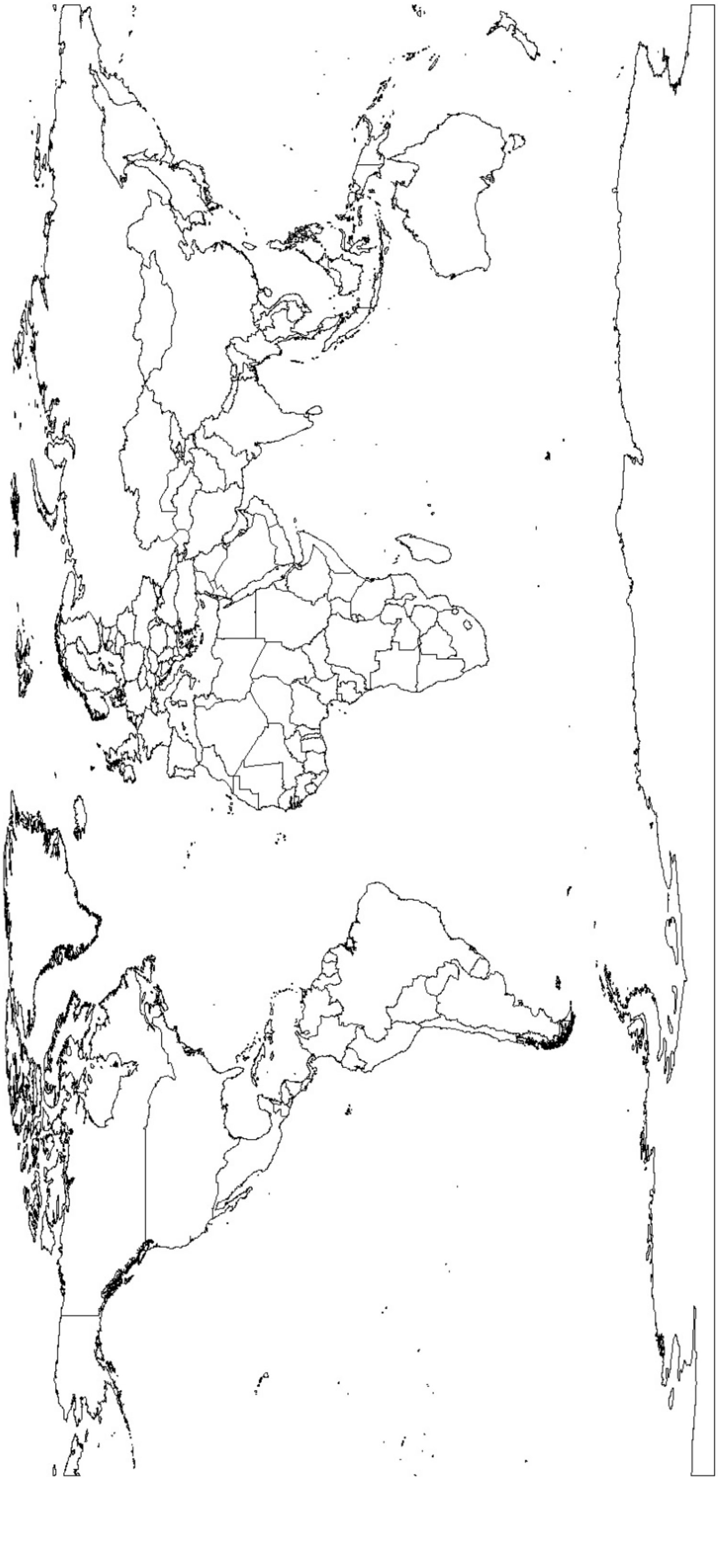
____

____

Part B

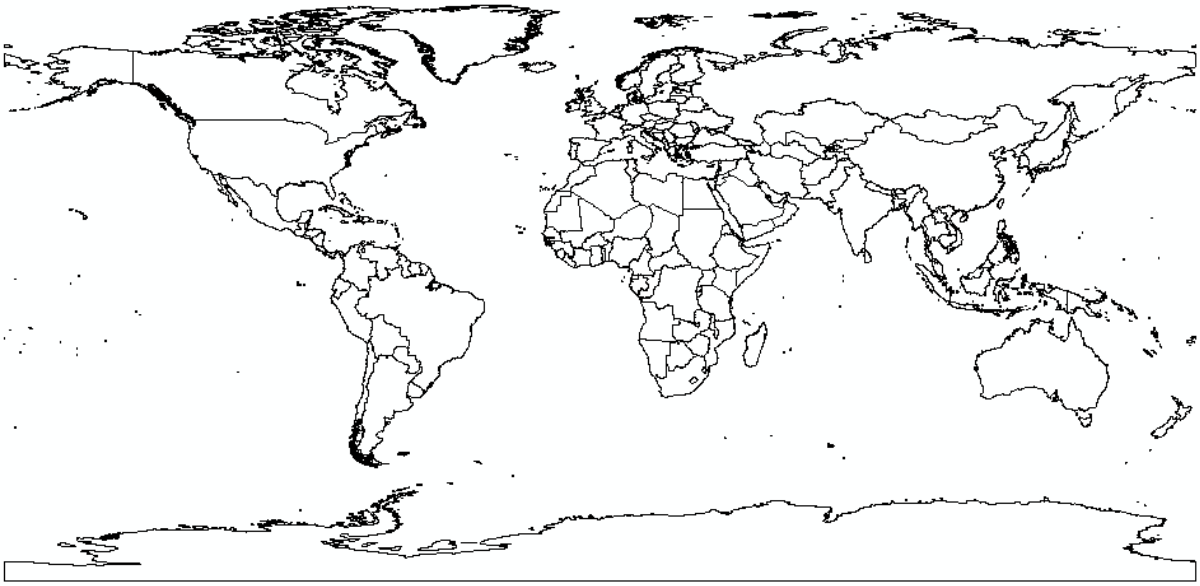
a) ACTIVITY – Explain what the following cartoon is suggesting

b) ACTIVITY – On the map below, indicate (by shading generally) the countries of the world that have a large INDUSTRIAL based economy.



Part C

ArcMap should be open on the computer with the following displayed



Explore the different map layers on the left-hand side by turning them ON and OFF.
You should expand the layers also by clicking your mouse on the plus (+) sign.

a) ***ACTIVITY – Which map layer/s could be used to determine whether a country produces fossil fuels? Explain***

____

____

____

____

b) ***ACTIVITY – Which map layer/s could be used to determine whether a country has a strong AGRICULTURAL based economy? Explain***

____

____

____

____

c) ACTIVITY – If a country has an INDUSTRY based economy, would you expect that they would consume a lot of fossil fuels? Explain

____

____

____

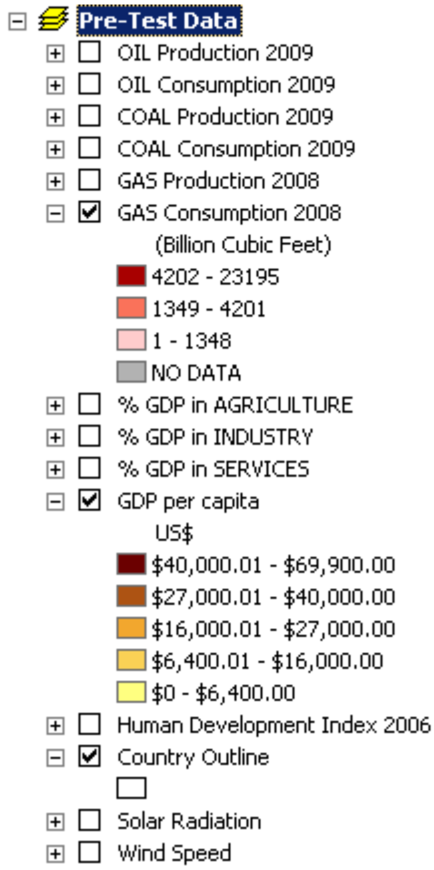
____

Part D

1 – Click the **Zoom to Full Extent** button  and make sure that the following map layers are expanded and turned ON (checked with a tick).

- **Gas Consumption 2008**
- **GDP per Capita**

The layers to left should look like this



2 – From the **Layer** dropdown menu, select **GAS Consumption 2008**

Click on the **Flicker** tool 

Click on the **Flicker** tool to stop the layers flickering

a) ACTIVITY – Explain any relationship that you see between Gas Consumption and GDP per capita?

____

____

____

____

Part E

Read the following and complete the activities below:

You work for the ***Alternative Energy Company (AEC)*** *which is an organisation that helps African countries to adopt new energy sources and technologies.*

You have recently returned from the country of Chad in Central Africa (shown below) where you were employed by the ***Minister of Energy*** *to investigate alternative energy sources for the country. The Minister is hoping to convince the Prime Minister to adopt new energy sources that are cheaper but have not yet been considered.*

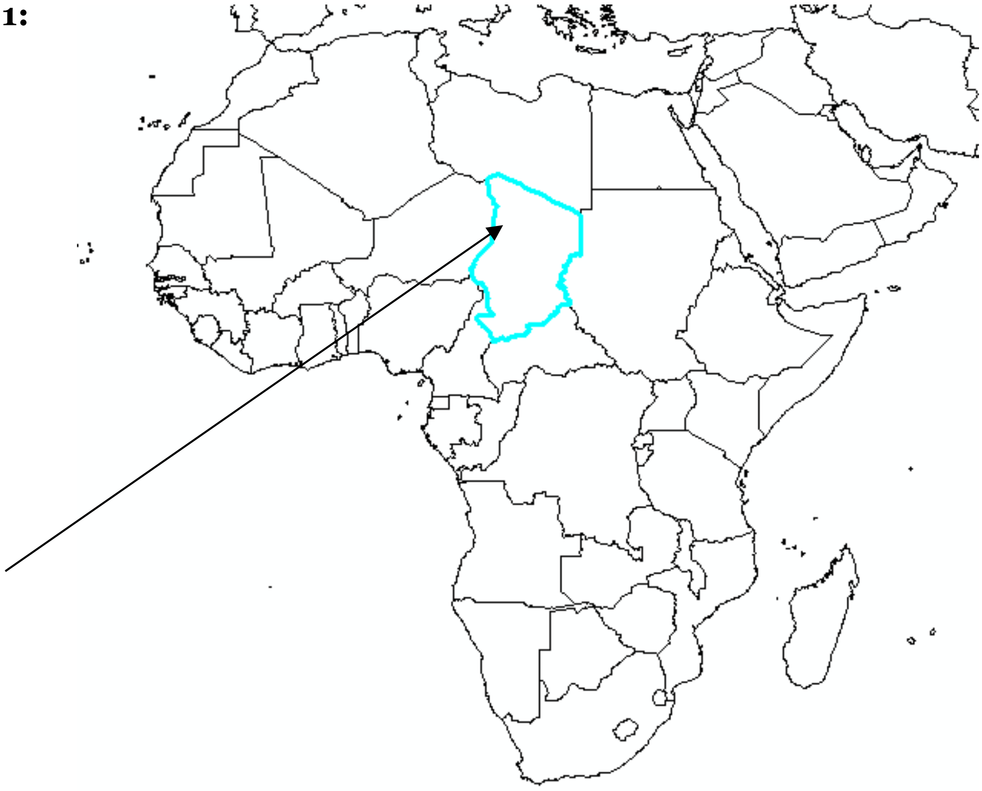
The Minister is relying on your final report to help convince the Prime Minister to make the change to alternative energy solutions.

a) ACTIVITY – You need to examine the source material and:

i. Explain why renewable energy resources should be considered by Chad due to their current economic situation

ii. Identify ONE alternative energy source and explain why you have chosen it.

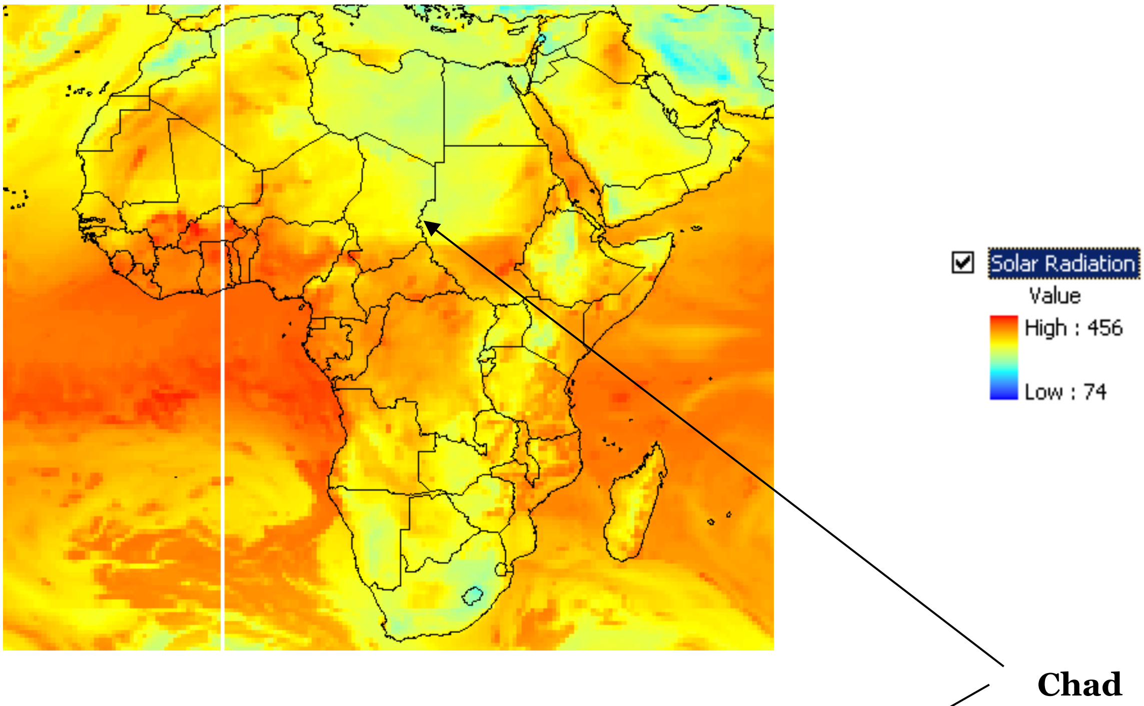
Source 1:



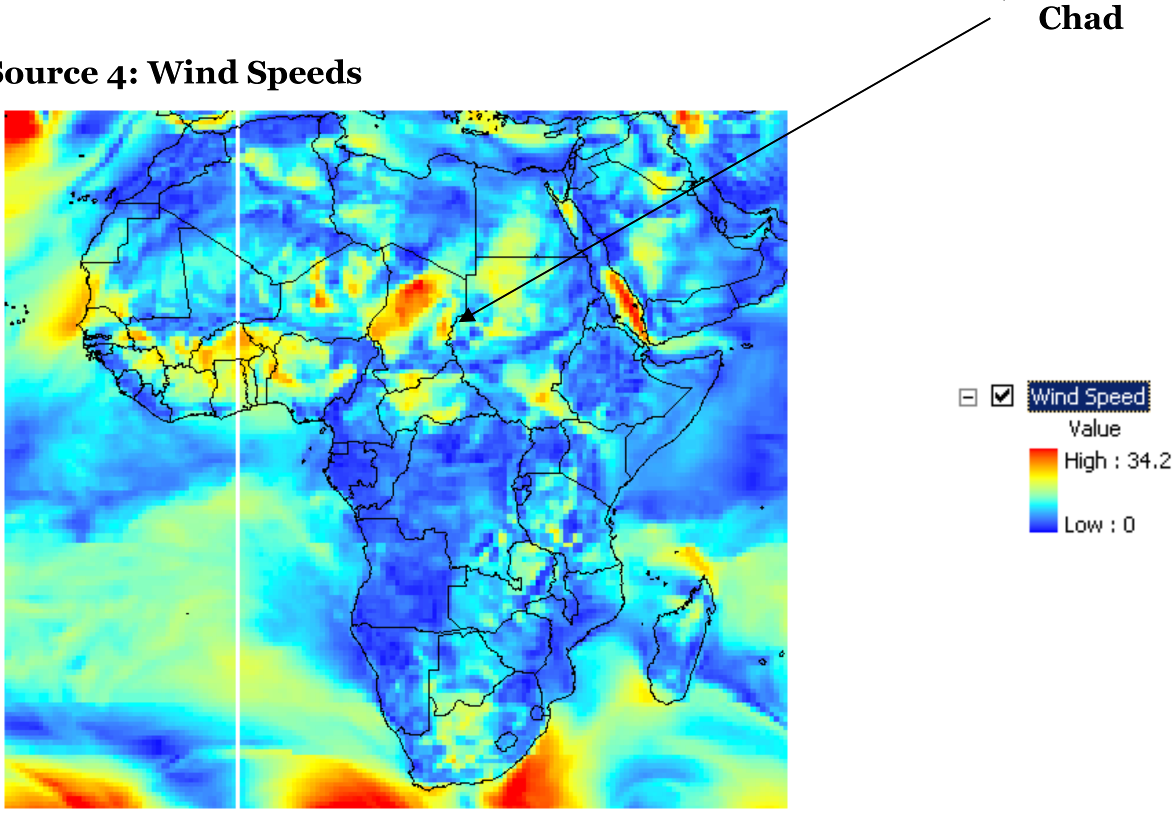
Source 2: Chad’s Economical Statistics

% Contribution of GDP	
AGRICULTURE	32.5 %
INDUSTRY	26.6 %
SERVICES	40.8%

Source 3: Solar Radiation



Source 4: Wind Speeds



i. ***ACTIVITY – Explain why renewable energy resources should be considered by Chad considering their current economic situation***

ii. ***ACTIVITY – Identify ONE alternative energy source and explain why you have chosen it.***

Part F

Imagine it is the future and you live in a highly ***developed*** *(wealthy) nation. You are also the* ***Energy/Resources Minister*** *in the government and responsible for ensuring that the country's economy continues to grow strongly.*

Unfortunately, fossil fuels are diminishing and there is pressure to move towards ***renewable energy sources****. With an election approaching and concerns about the environment growing, public support for your government is diminishing and swinging to the* ***Environmental Political Party.*** *Their policies support the use of sustainable and renewable energy resources.*

a) ACTIVITY – your task is to devise a new strategy that your government can take to the next election. You must identify and THREE key strategies that your government will adopt and explain why you have chosen them (in rank order).

1 - ____

____

____

2 - ____

____

____

3 - ____

____

____

Part G – Questionnaire

Complete the following questions by placing a ticking in the box that is most appropriate. The following scales apply.

Strongly Disagree	Mildly Disagree	Disagree	Neutral	Agree	Mildly Agree	Strongly Agree

Attitude towards the use of technology in Geography:	Strongly Disagree	Mildly Disagree	Disagree	Neutral	Agree	Mildly Agree	Strongly Agree
1 – I feel that computers help me to do more interesting work in Geography	☐	☐	☐	☐	☐	☐	☐
2 – I feel confident using computers in my studies of Geography	☐	☐	☐	☐	☐	☐	☐
3 – I wish I had more chance to use computers in my studies of Geography	☐	☐	☐	☐	☐	☐	☐
4 – I wish my teacher used technology generally more in Geography classes	☐	☐	☐	☐	☐	☐	☐
5 – I feel that computers can help me to conduct effective research in Geography	☐	☐	☐	☐	☐	☐	☐

Attitude towards GIS Technology:	Strongly Disagree	Mildly Disagree	Disagree	Neutral	Agree	Mildly Agree	Strongly Agree
1 – I feel comfortable using technologies like GIS in Geography	☐	☐	☐	☐	☐	☐	☐
2 – I feel that GIS is a technology that can help me better understand maps in Geography	☐	☐	☐	☐	☐	☐	☐
3 – I feel that GIS is a technology that can help me better understand patterns in Geography	☐	☐	☐	☐	☐	☐	☐
4 – I enjoy investigating and exploring the Geographic data that is displayed in a GIS	☐	☐	☐	☐	☐	☐	☐
5 – I feel that a GIS is difficult to use and as a result it distracts me from the topic we are studying	☐	☐	☐	☐	☐	☐	☐

Attitude towards Learning & Pedagogy in Geog:	Strongly Disagree	Mildly Disagree	Disagree	Neutral	Agree	Mildly Agree	Strongly Agree
1 – I feel that I learn best in Geography when the teacher provides regular instructions during the lesson	☐	☐	☐	☐	☐	☐	☐
2 – I feel that I learn best in Geography when I work individually and on my own	☐	☐	☐	☐	☐	☐	☐
3 – I feel that I learn best in Geography when given work sheets with clear step-by-step instructions	☐	☐	☐	☐	☐	☐	☐
4 – I feel that I learn best in Geography when I am given a problem to solve or an issue to investigate	☐	☐	☐	☐	☐	☐	☐
5 – I feel that I learn best when I am given lots of resources and additional information during the lesson	☐	☐	☐	☐	☐	☐	☐

ENERGY

POST-TEST

GIS Activity

Year 9

NAME: ____

GROUP: _______________________

DATE OF BIRTH: _____________________________

PRE-TEST

Part A

a) ACTIVITY – What do you understand the following terms to mean?

Fossil Fuel

____

____

Renewable Energy

____

____

Industrialised Nation

____

____

Developed World

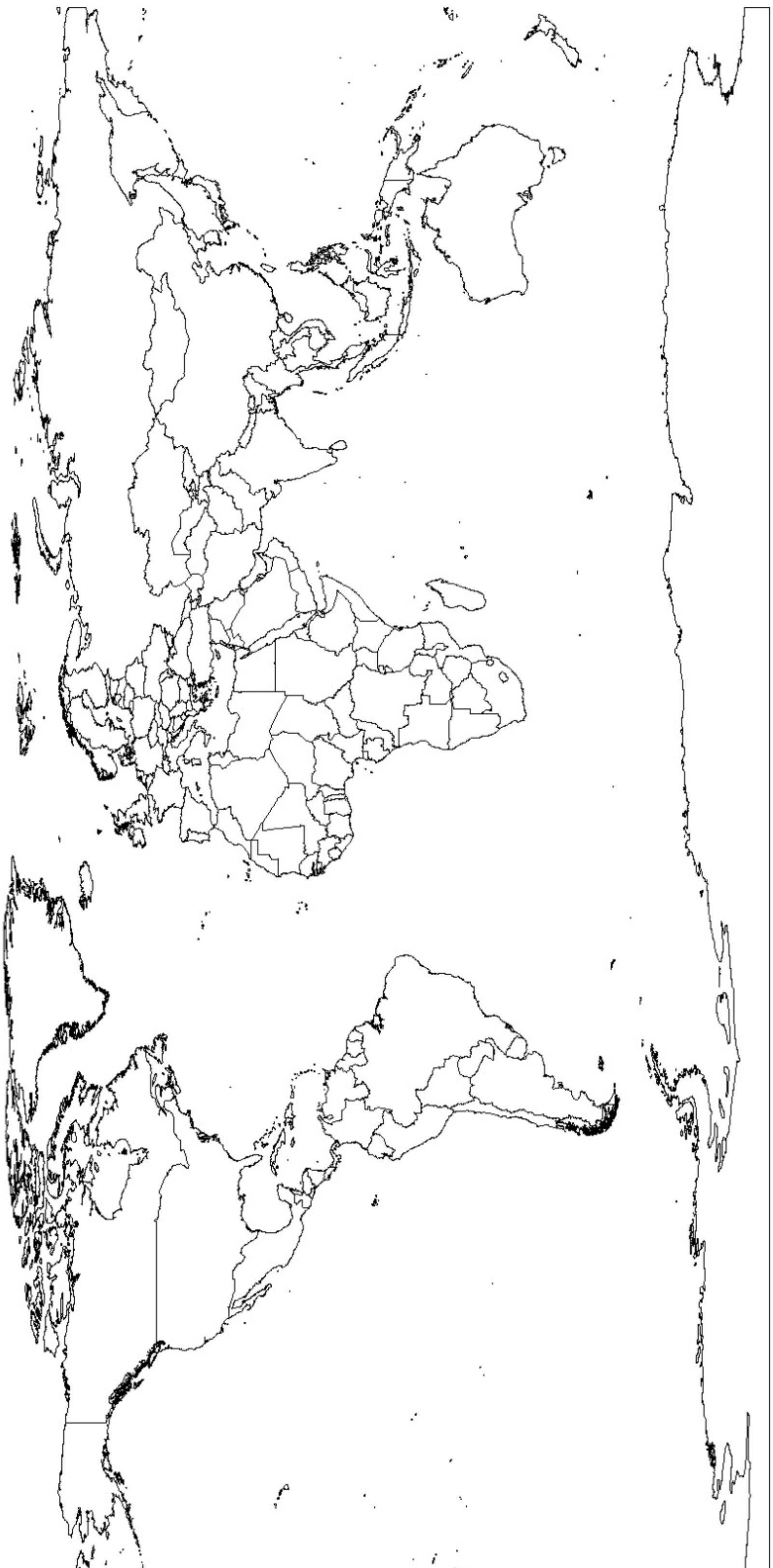
____

____

Part B

a) ACTIVITY – Explain what the following image is suggesting

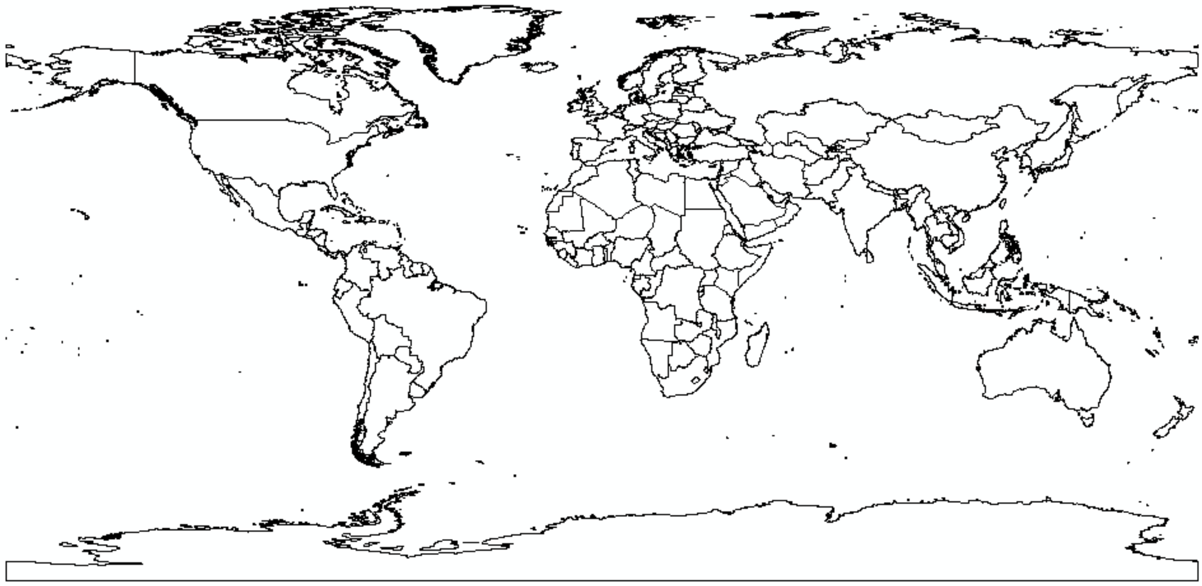
b) ACTIVITY – On the map below, indicate (by shading generally) the countries of the world that have a large



SERVICE based economy.

Part C

ArcMap should be open on the computer with the following displayed



Explore the different map layers on the left-hand side by turning them ON and OFF.

You should expand the layers also by clicking your mouse on the plus (+) sign.

a) ***ACTIVITY – Which map layer/s could be used to determine whether a country consumes fossil fuels? Explain***

____

____

____

____

b) ***ACTIVITY – Which map layer/s could be used to determine whether a country has a strong SERVICE based economy? Explain***

____

____

____

____

c) ACTIVITY – If a country has an AGRICULTURAL based economy, would you expect that they would consume a lot of fossil fuels? Explain

____

____

____

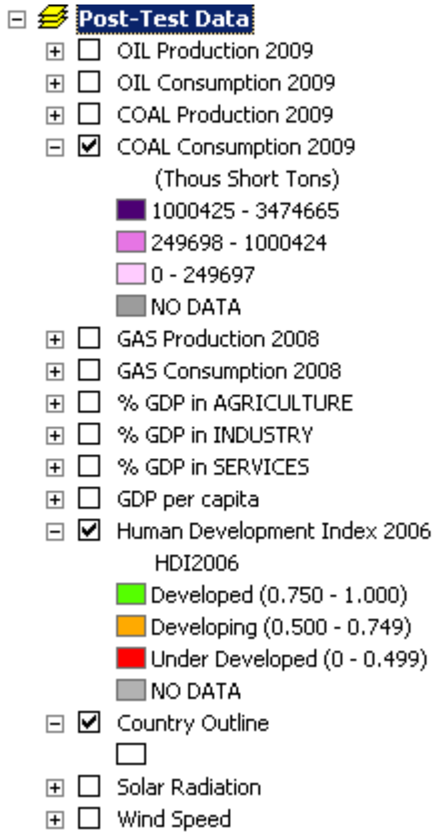
____

Part D

1 – Click the **Zoom to Full Extent** button and make sure that the following map layers are expanded and turned ON (checked with a tick).

- **Coal Consumption 2008**
- **Human Development Index 2006**

The layers to left should look like this



2 – From the **Layer** dropdown menu, select **Coal Consumption 2009**

Click on the **Flicker** tool

Click on the **Flicker** tool to stop the layers flickering

a) ACTIVITY – Explain any relationship that you see between Coal Consumption 2009 and Human Development Index 2006?

____

____

____

____

Part E

Read the following and complete the activities below:

The United Nations has decided to donate a large amount of money to ONE country who invests in one or more ***large scale*** *renewable energy projects.*

The selected country must have suitable conditions for large scale (widespread) Wind and Solar projects to be built and they must be widespread. Applications from developing countries will also be considered favourably but the country must have a strong economy. While a strong industry is important, the country must have a strong service sector to manage the project.

China and India have both submitted applications. As an employee of the United Nations, you are required to evaluate both applications. Your job is to decide which country has the most potential to develop a renewable energy program on a large or widespread scale. Your decision must be supported by a suitable justification or explanation.

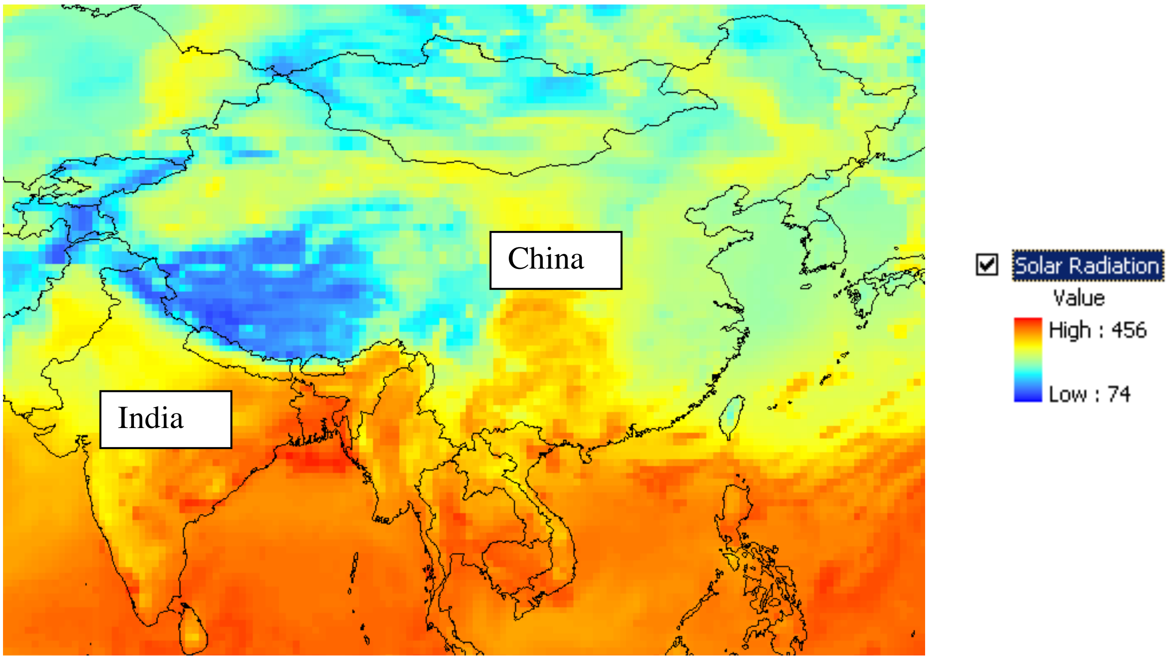
a) ACTIVITY – You need to examine the source material and decide which country has the most potential to develop a renewable energy program on a large scale. Explain with reasons why.

Source 1:

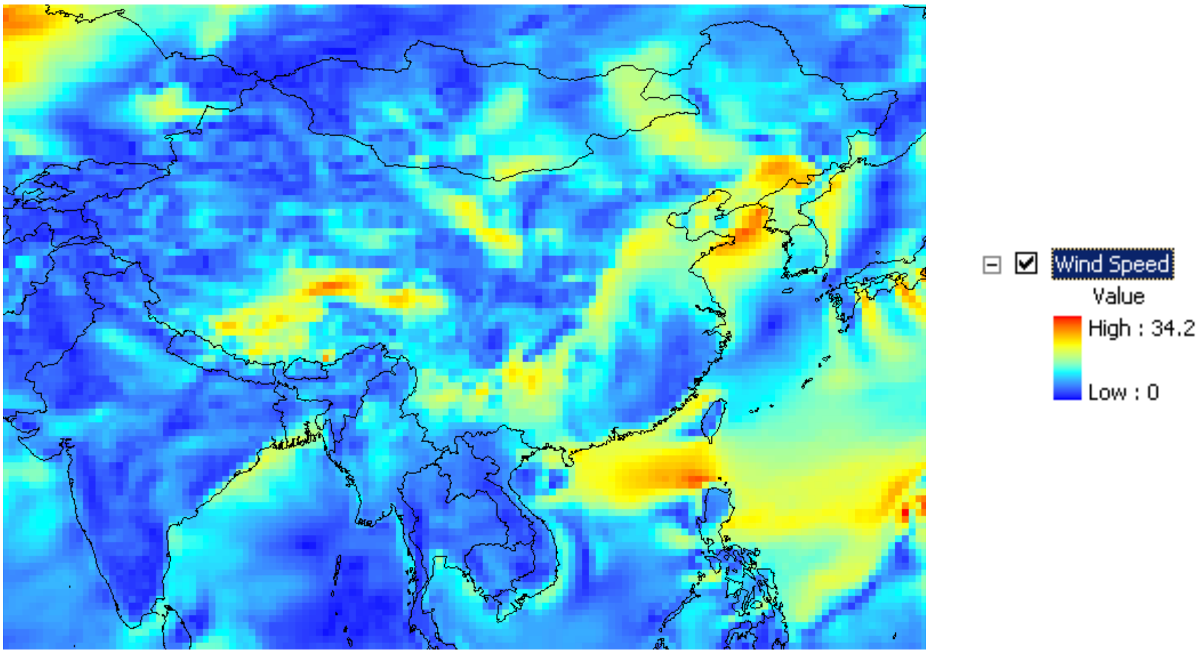
Source 2: Economical Statistics for each country

INDIA		CHINA	
% Contribution of GDP		% Contribution of GDP	
AGRICULTURE	19.9 %	AGRICULTURE	11.9 %
INDUSTRY	19.3 %	INDUSTRY	48.1 %
SERVICES	60.7%	SERVICES	40%

Source 3: Solar Radiation



Source 4: Wind Speeds



Your Evaluation

Part F

Imagine it is the future and you live in a highly ***developed*** *(wealthy) nation. You are also the* ***Energy/Resources Minister*** *in the government and responsible for ensuring that the country's economy continues to grow strongly.*
Unfortunately, fossil fuels are diminishing and there is pressure to move towards ***renewable energy sources****. With an election approaching and concerns about the environment growing, public support for your government is diminishing and swinging towards the* ***Environmental Political Party.*** *Their policies support the use of sustainable and renewable energy resources.*

a) ACTIVITY – your task is to devise a new strategy that your government can take to the next election. You must identify and THREE key strategies that your government will adopt and explain why you have chosen them (in rank order i.e.: 1 Top Priority etc).

1 - ____

____

____

____

2 - ____

____

____

____

3 - ____

____

____

____

Part G – Questionnaire

Complete the following questions by placing a ticking in the box that is most appropriate. The following scales apply.

Strongly Disagree	Mildly Disagree	Disagree	Neutral	Agree	Mildly Agree	Strongly Agree

PART A	**Strongly Disagree**	**Mildly Disagree**	**Disagree**	**Neutral**	**Agree**	**Mildly Agree**	**Strongly Agree**
1 – I feel that computers help me to do more interesting work in Geography	☐	☐	☐	☐	☐	☐	☐
2 – I feel confident using computers in my studies of Geography	☐	☐	☐	☐	☐	☐	☐
3 – I wish I had more chance to use computers in my studies of Geography	☐	☐	☐	☐	☐	☐	☐
4 – I wish my teacher used technology generally more in Geography classes	☐	☐	☐	☐	☐	☐	☐
5 – I feel that computers can help me to conduct effective research in Geography	☐	☐	☐	☐	☐	☐	☐

PART B	**Strongly Disagree**	**Mildly Disagree**	**Disagree**	**Neutral**	**Agree**	**Mildly Agree**	**Strongly Agree**
1 – I feel comfortable using technologies like GIS in Geography	☐	☐	☐	☐	☐	☐	☐
2 – I feel that GIS is a technology that can help me better understand maps in Geography	☐	☐	☐	☐	☐	☐	☐
3 – I feel that GIS is a technology that can help me better understand patterns in Geography	☐	☐	☐	☐	☐	☐	☐
4 – I enjoy investigating and exploring the Geographic data that is displayed in a GIS	☐	☐	☐	☐	☐	☐	☐
5 – I feel that a GIS is difficult to use and as a	☐	☐	☐	☐	☐	☐	☐

result it distracts me from the topic we are studying							

PART C	Strongly Disagree	Mildly Disagree	Disagree	Neutral	Agree	Mildly Agree	Strongly Agree
1 – I feel that I learn best in Geography when the teacher provides regular instructions during the lesson	☐	☐	☐	☐	☐	☐	☐
2 – I feel that I learn best in Geography when I work individually and on my own	☐	☐	☐	☐	☐	☐	☐
3 – I feel that I learn best in Geography when given work sheets with clear step-by-step instructions	☐	☐	☐	☐	☐	☐	☐
4 – I feel that I learn best in Geography when I am given a problem to solve or an issue to investigate	☐	☐	☐	☐	☐	☐	☐
5 – I feel that I learn best when I am given lots of resources and additional information during the lesson	☐	☐	☐	☐	☐	☐	☐

PART D	Strongly Disagree	Mildly Disagree	Disagree	Neutral	Agree	Mildly Agree	Strongly Agree
1 – I felt that I was able to use information from the GIS to understand the patterns of energy use around the world	☐	☐	☐	☐	☐	☐	☐
2 – I felt that I was able to apply information from the GIS to understand the topic of energy	☐	☐	☐	☐	☐	☐	☐
3 – I felt that I was able to analyse information in the GIS to understand differences between energy production and consumption	☐	☐	☐	☐	☐	☐	☐
4 – I felt that I was able to evaluate information from the GIS to come up with solutions to the problems of the energy around the world	☐	☐	☐	☐	☐	☐	☐
5 – I found that the GIS helped me to think of other questions relating to the topic of Energy	☐	☐	☐	☐	☐	☐	☐
6 – I found that the GIS increased my level of motivation to learn more about the topic of Energy	☐	☐	☐	☐	☐	☐	☐
7 – I feel that the GIS helps me learn better than	☐	☐	☐	☐	☐	☐	☐

traditional resources such as worksheets and handouts							
8 – I felt that my understanding of Energy improved due to the teacher alone	☐	☐	☐	☐	☐	☐	☐

PART E

a) What did you like about this lesson?

____

____

____

____

b) What didn't you like about this lesson?

____

____

____

____

c) Do you have any other comments about the lesson?

____

____

____

____

d) In your opinion, how do you think this lesson could have been improved to help you better understand the topic of energy?

____

____

____

____

e) How do you think the GIS could have been more effectively used to help you understand the topic of energy in this lesson?

____

____

____

Appendix C: Standardised mark scheme for the Pre-test and Post-test

DEVELOPMENT

<u>PRE-TEST</u>
<u>MARKING CRITERIA</u>

GIS Activity
Year 9

NAME: ______________________________________

GROUP: ________________________

DATE OF BIRTH: ______________________________

PRE-TEST

Part A

a) ACTIVITY – What do you understand the following terms to mean?

Development: The process of development involves improving the quality of people's life through increasing per capita income, reducing poverty and enhancing individuals' economic opportunities.

Criteria	Marks
• Student demonstrates a clear understanding of **development** by providing a detailed and accurate description of the term	2
• Student demonstrates some understanding of **development** by providing a partially accurate description of the term	1
• Student demonstrates no understanding of **development** by failing to provide a description of the term OR by providing an inaccurate definition of the term	0

Global Inequality: refers to the unequal access to food, shelter, water, health care and education of people in different parts of the world.

Criteria	Marks
• Student demonstrates a clear understanding of **global inequality** by providing a detailed and accurate description of the term	2
• Student demonstrates some understanding of **global inequality** by providing a partially accurate description of the term	1
• Student demonstrates no understanding of **global inequality** by failing to provide a description of the term OR by providing an inaccurate definition of the term	0

Wealth: refers to a great quantity or store of money, possessions, property or other riches.

Criteria	Marks
• Student demonstrates a clear understanding of **wealth** by providing a detailed and accurate description of the term	2
• Student demonstrates some understanding of **wealth** by providing a partially accurate description of the term	1
• Student demonstrates no understanding of **wealth** by failing to provide a description of the term OR by providing an inaccurate definition of the term	0

Gross Domestic Product (GDP) per Capita: represents the per person money value of all goods and services a country produces in a year divided by the population.

Criteria	Marks
• Student demonstrates a clear understanding of **Gross Domestic Product (GDP) per Capita** by providing a detailed and accurate description of the term	2
• Student demonstrates some understanding of **Gross Domestic Product (GDP) per Capita** by providing a partially accurate description of the term	1
• Student demonstrates no understanding of **Gross Domestic Product (GDP) per Capita** by failing to provide a description of the term OR by providing an inaccurate definition of the term	0

Part B

a) ACTIVITY – Examine the two photos below and comment on the differences.

Criteria	Marks
• Student provides accurate and clear reference to the differences between the photos including reference to standards of living in BOTH photographs such as quality of housing, sanitation, ground surface, clothing, appearance	3
• Student provides general reference to the differences between the photos including some reference to standards of living in BOTH photographs such as quality of housing, sanitation, ground surface, clothing, appearance	2
• Student provides limited reference to the differences between the photos including some reference to standards of living in BOTH photographs such as quality of housing, sanitation, ground surface, clothing, appearance OR • Provides reference to standards of living in ONE photograph	1
• Student provides NO accurate reference to the differences between the photos	0

b) ACTIVITY – Describe TWO things that could be used to determine a person's quality of life?

Criteria	Marks
• Student provides a clear and accurate description of TWO things that could be used to determine a person's quality of life including: access to food, access to health care, education, shelter and clean water	2
• Student provides a partially accurate description of TWO things that could be used to determine a person's quality of life including: access to food, access to health care, education, shelter and clean water OR • Student provides an accurate OR partially accurate description of ONE thing that could be used to determine a person's quality of life including: access to food, access to health care, education, shelter and clean water	1
• Student provides an inaccurate OR nil description of things that could be used to determine a person's quality of life	0

c) ACTIVITY – On the map below, indicate (by shading generally) those countries of the world that you understand to be the most economically advanced.

Criteria	Marks
• Student demonstrates a clear knowledge of countries that are the most economically advanced by correctly shading FOUR or more countries/continents including North America, Australia, Japan, UK, Western Europe etc	3
• Student demonstrates some knowledge of countries that are the most economically advanced by correctly shading between TWO and FOUR countries/continents including North America, Australia, Japan, UK, Western Europe etc	2
• Student demonstrates limited knowledge of countries that are the most economically advanced by correctly shading LESS than FOUR countries/continents including North America, Australia, Japan, UK, Western Europe etc	1
• Student demonstrates NO knowledge of countries that are the most economically advanced by failing to shade any country correctly	0

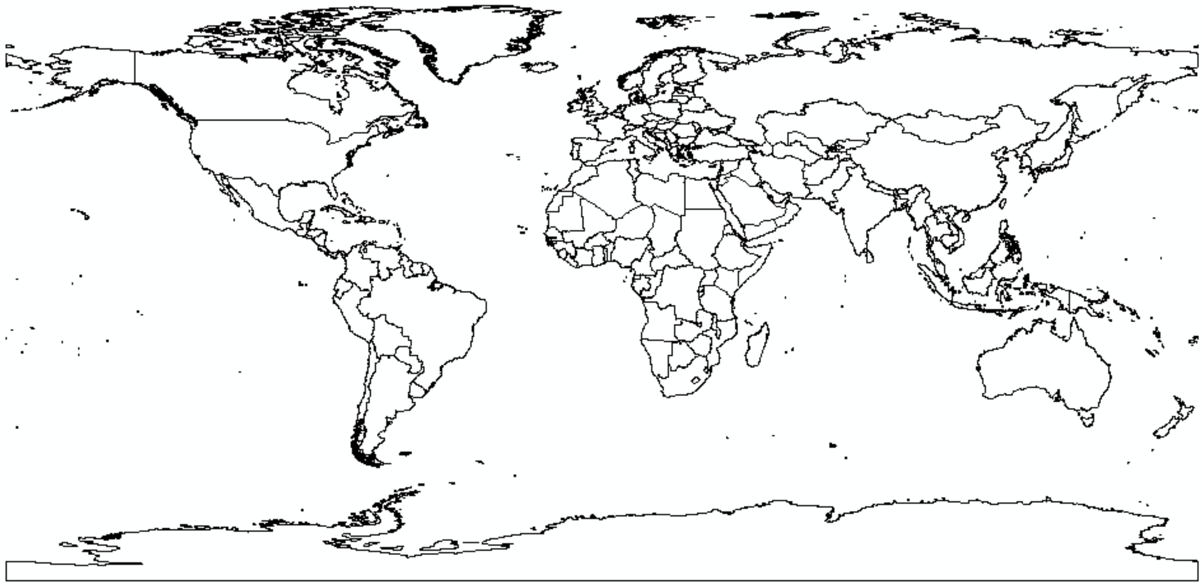
Part C

1 – MALNOURISHMENT DEFINITION: not having enough food to develop or function normally

a) ACTIVITY – How could a world map showing patterns of child malnourishment be used to understand whether a country is developed or not?

Criteria	Marks
• Student clearly and accurately notes that countries with high levels of child malnourishment have poor or limited access to food and are therefore most likely to be developing or have poor standards of living; vice versa for countries with low levels of child malnourishment AND	4
• Student clearly and accurately notes that countries with high levels of child malnourishment have poor or limited access to food AND/OR • Notes that countries with high levels of child malnourishment are most likely to be developing or have poor standards of living	3
• Student makes a general reference to the fact that countries with high levels of child malnourishment have poor access to food OR therefore is likely to be developing or have poor standards of living; vice versa for countries with low levels of child malnourishment AND	2
• Student makes NO connection to the fact that countries with high levels of child malnourishment have poor access to food OR therefore is likely to be developing or have poor standards of living; vice versa for countries with low levels of child malnourishment	1

2 – Using ArcMap, the following should be displayed



Explore the different map layers on the left-hand side by turning them ON and OFF. You should expand the layers also by clicking your mouse on the plus (+) sign.

Complete the following activities.

b) ACTIVITIES – Which map layers could be used to determine whether a country has a strong economy or not? Explain

Criteria	Marks
• Student clearly states BOTH: Population 65 years or older Years of Schooling	2
• Student clearly states EITHER: Population 65 years or older OR Years of Schooling	1
• Student fails to state EITHER: Population 65 years or older OR Years of Schooling	0

c) ACTIVITIES – Which map layers could be used to determine the standard of living for people living in the developing world? Explain

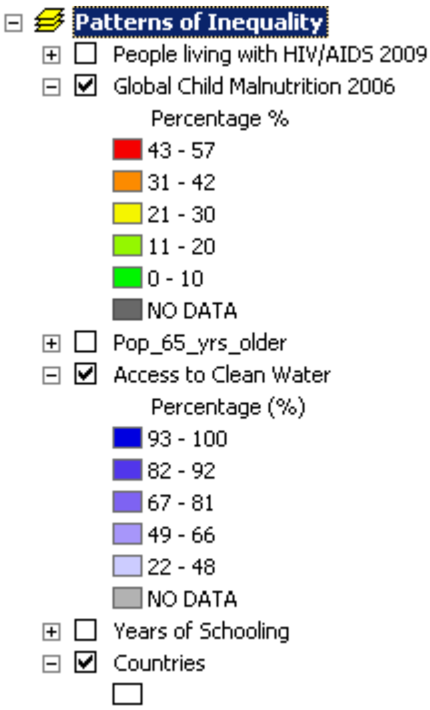
Criteria	Marks
• Student clearly states at least FOUR of the following: People living with HIV/AIDS 2009 Global Child Malnutrition 2006 Pop_65_yrs_older Access to Clean Water Years of Schooling • Provides a clear and concise explanation	2
• Student clearly states at least TWO of the following: People living with HIV/AIDS 2009 Global Child Malnutrition 2006 Pop_65_yrs_older Access to Clean Water Years of Schooling • Provides a general explanation	1
• Student fails to state EITHER: People living with HIV/AIDS 2009 Global Child Malnutrition 2006 Pop_65_yrs_older Access to Clean Water Years of Schooling • Provides a limited explanation	0

Part D

1 – Click the **Zoom to Full Extent** button  and make sure that the following map layers are expanded and turned ON (checked with a tick).

- **Global Child Malnutrition 2006**
- **Access to Clean Water**

The layers to left should look like this



2 – From the **Effects** dropdown menu, select **Global Child Malnutrition 2006**

Click on the **Swipe** tool 

Click your mouse on the top of the screen and then drag the swipe tool down the screen. You should see the different layers.

a) ACTIVITY – Describe any patterns that you see between Global Malnutrition 2006 (%) AND Access to Clean Water

Criteria	Marks
• Student clearly and accurately refers to BOTH Malnutrition and clean water access: - Countries in India and Central and Eastern Africa have HIGH levels of Child Malnutrition - Countries in Africa and Central Asia have POOR access to clean water AND • Student notes the overlap between the two layers and that there is likely to be a strong link between the two layers	3
• Student generally refers to BOTH Malnutrition and clean water access: - Countries in India and Central and Eastern Africa have HIGH levels of Child Malnutrition - Countries in Africa and Central Asia have POOR access to clean water AND/OR • Student notes some overlap between the two layers and that there is likely to be some link between the two layers	2
• Student makes some reference to EITHER Malnutrition OR clean water: - Countries in India and Central and Eastern Africa have HIGH levels of Child Malnutrition - Countries in Africa and Central Asia have POOR access to clean water OR • Student notes some overlap between the two layers and that there is likely to be a strong link between the two layers	1
• Student makes no reference to any connection between the two layers AND/OR incorrectly identifies areas of malnutrition and clean water	0

b) ACTIVITY – Explain reasons for any patterns that you see.

Criteria	Marks
• Student makes a clear and distinct reference to the fact that: - countries with HIGH levels of Child Malnutrition are most likely developing and therefore have limited access to healthy food and nutrition AND - countries with POOR access to Water are most likely developing and therefore unable to provide safe, clean drinking water	3
• Student makes general reference to the fact that: - countries with HIGH levels of Child Malnutrition are most likely developing and therefore have limited access to healthy food and nutrition AND - countries with POOR access to Water are most likely developing and therefore unable to provide safe, clean drinking water	2
• Student makes some reference to the fact that: - countries with HIGH levels of Child Malnutrition are most likely developing and therefore have limited access to healthy food and nutrition OR - countries with POOR access to Water are most likely developing and therefore unable to provide safe, clean drinking water	1
• Student makes NO reference to the fact that: - countries with HIGH levels of Child Malnutrition are most likely developing and therefore have limited access to healthy food and nutrition OR - countries with POOR access to Water are most likely developing and therefore unable to provide safe, clean drinking water	0

Part E

a) ACTIVITY – Imagine that you are a 15-year-old boy living in a poor village in a developing country. Identify THREE things that your family would most benefit from and explain how they would improve the quality of your family's life.

Criteria	Marks
• Student accurately interprets the activity and thoughtfully identifies THREE things that their family would most benefit from in a developing country • Clearly explains how they would improve the quality of life for the family • The writing demonstrates a high level of understanding of the activity and provides a clear and concise response	3
• Student interprets the activity and identifies THREE things that their family would most benefit from in a developing country • Provides a general explanation of how they would improve the quality of life for the family • The writing demonstrates a good understanding of the activity and provides a sound response	2
• Student identifies less than THREE things that their family would most benefit from in a developing country • Provides a general explanation of how they would improve the quality of life for the family • The writing demonstrates some understanding of the activity and provides a limited response	1
• Student identifies less than THREE things that their family would most benefit from in a developing country • Provides a limited explanation of how they would improve the quality of life for the family • The writing demonstrates limited understanding of the activity and provides a poor response	0

Part F

a) ACTIVITY – You work for one of the world's major Aid organisations. Your organisation was created to support and provide assistance to people living in the developing world.

Because of your understanding of developing countries, you have been asked by the Chairman of the Aid organisation to create a new strategy for improving the quality of life of people living in developing countries. Explain the strategy below.

Criteria	Marks
• Student accurately interprets the activity and thoughtfully provides a unique new strategy for improving the quality of life of people living in developing countries • Clearly explains the strategy and distinctly describes the theory behind its development • The writing demonstrates a high level of understanding of the activity and provides a clear and concise response	4
• Student interprets the activity and provides a good strategy for improving the quality of life of people living in developing countries • Provides a general explanation of the strategy and describes the theory behind its development • The writing demonstrates a good level of understanding of the activity and provides a clear and concise response	3
• Student shows some evidence of interpreting the activity and provides a general strategy for improving the quality of life of people living in developing countries • Provides some explanation of the strategy AND/OR describes the theory behind its development • The writing demonstrates a general level of understanding of the activity and provides a general response	2
• Student shows limited evidence of having interpreted the activity and provides a limited strategy for improving the quality of life of people living in developing countries • Provides a limited explanation of the strategy AND/OR some reference to the theory behind its development • The writing demonstrates a limited level of understanding of the activity and provides a general response	1
• Student shows NO evidence of having interpreted the activity OR provides NO strategy for improving the quality of life of people living in developing countries • Provides a poor explanation of the strategy AND/OR poor reference to the theory behind its development • The writing demonstrates a poor level of understanding of the activity and provides a general response	0

DEVELOPMENT

POST-TEST MARKING CRITERIA

GIS Activity
Year 9

NAME: ____________________________________

GROUP: ______________________

DATE OF BIRTH: ____________________________

POST-TEST

Part A

a) ACTIVITY – What do you understand the following terms to mean?

Development: The process of development involves improving the quality of people's life through increasing per capita income, reducing poverty and enhancing individuals' economic opportunities.

Criteria	Marks
• Student demonstrates a clear understanding of **development** by providing a detailed and accurate description of the term	2
• Student demonstrates some understanding of **development** by providing a partially accurate description of the term	1
• Student demonstrates no understanding of **development** by failing to provide a description of the term OR by providing an inaccurate definition of the term	0

Global Inequality: refers to the unequal access to food, shelter, water, health care and education of people in different parts of the world.

Criteria	Marks
• Student demonstrates a clear understanding of **global inequality** by providing a detailed and accurate description of the term	2
• Student demonstrates some understanding of **global inequality** by providing a partially accurate description of the term	1
• Student demonstrates no understanding of **global inequality** by failing to provide a description of the term OR by providing an inaccurate definition of the term	0

Human Development Index: is a statistic that combines income, life expectancy and literacy levels of a particular country.

Criteria	Marks
• Student demonstrates a clear understanding of **Human Development Index** by providing a detailed and accurate description of the term	2
• Student demonstrates some understanding of **Human Development Index** by providing a partially accurate description of the term	1
• Student demonstrates no understanding of **Human Development Index** by failing to provide a description of the term OR by providing an inaccurate definition of the term	0

Poverty: refers to coping without the resources (food, clothing, shelter) necessary for life.

Criteria	Marks
• Student demonstrates a clear understanding of **Poverty** by providing a detailed and accurate description of the term	2
• Student demonstrates some understanding of **Poverty** by providing a partially accurate description of the term	1
• Student demonstrates no understanding of **Poverty** by failing to provide a description of the term OR by providing an inaccurate definition of the term	0

Part B

a) ACTIVITY – Examine the two photos below and comment on the differences.

Criteria	Marks
• Student provides accurate and clear reference to the differences between the photos including reference to standards of living in BOTH photographs such as quality of housing, sanitation, ground surface, clothing, appearance	3
• Student provides general reference to the differences between the photos including some reference to standards of living in BOTH photographs such as quality of housing, sanitation, ground surface, clothing, appearance	2
• Student provides limited reference to the differences between the photos including some reference to standards of living in BOTH photographs such as quality of housing, sanitation, ground surface, clothing, appearance OR • Provides reference to standards of living in ONE photograph	1
• Student provides NO accurate reference to the differences between the photos	0

b) ACTIVITY – Describe TWO factors things that can cause inequalities in living standards

Criteria	Marks
• Student provides a clear and accurate description of TWO factors that can cause inequalities in living standards including variations in the access to food, health care, education, shelter and clean water	2
• Student provides a partially accurate description of TWO factors that can cause inequalities in living standards including variations in the access to food, health care, education, shelter and clean water OR • Student provides an accurate OR partially accurate description of ONE thing that can cause inequalities in living standards including variations in the access to food, health care, education, shelter and clean water	1
• Student provides an inaccurate OR nil description of factors that can cause inequalities in living standards including variations in the access to food, health care, education, shelter and clean water	0

c) ***ACTIVITY – On the map below, indicate (by shading generally) those countries of the world that you understand to have the longest life expectancy.***

Criteria	Marks
• Student demonstrates a clear knowledge of countries that are the most economically advanced by correctly shading FOUR or more countries/continents including North America, Australia, Japan, UK, Western Europe etc	3
• Student demonstrates some knowledge of countries that are the most economically advanced by correctly shading between TWO and FOUR countries/continents including North America, Australia, Japan, UK, Western Europe etc	2
• Student demonstrates limited knowledge of countries that are the most economically advanced by correctly shading LESS than FOUR countries/continents including North America, Australia, Japan, UK, Western Europe etc	1
• Student demonstrates NO knowledge of countries that are the most economically advanced by failing to shade any country correctly	0

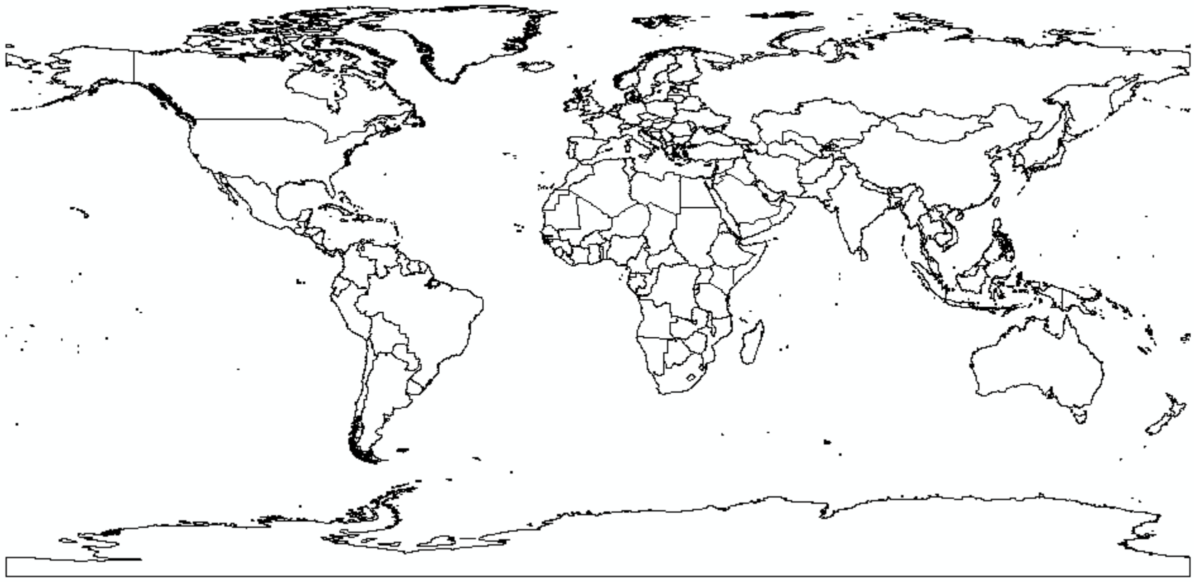
Part C

1 – LITERACY DEFINITION: the ability to read and write

a) ACTIVITY – How could a map which shows literacy rates be used to understand whether a country is developed or not?

Criteria	Marks
• Student clearly and accurately notes that countries with low levels of literacy rates have poor or limited access to education and are therefore most likely to be developing; vice versa for countries with high levels of literacy rates	4
• Student clearly and accurately notes that countries with low levels of literacy rates have poor or limited access to education AND/OR • Notes that countries with low levels of literacy rates are most likely to be developing	3
• Student makes a general reference to the fact that countries with low levels of literacy rates have poor access to education OR is likely to be developing; vice versa for countries with high levels of literacy rates	2
• Student makes NO connection to the fact that countries with high levels of child malnourishment have poor access to food OR therefore is likely to be developing or have poor standards of living; vice versa for countries with low levels of child malnourishment	1

2 – Using ArcMap, the following should be displayed



Explore the different map layers on the left-hand side by turning them ON and OFF. You should expand the layers also by clicking your mouse on the plus (+) sign.

Complete the following activities.

b) ACTIVITY – Which map or maps could be used to determine whether a country has a good standard of health? Explain

Criteria	Marks
• Student clearly states at least FOUR of the following: People living with HIV/AIDS 2009 Global Child Malnutrition 2006 Pop_65_yrs_older Access to Clean Water • Provides a clear and concise explanation	2
• Student clearly states at least TWO of the following: People living with HIV/AIDS 2009 Global Child Malnutrition 2006 Pop_65_yrs_older Access to Clean Water • Provides a general explanation	1
• Student fails to state EITHER: People living with HIV/AIDS 2009 Global Child Malnutrition 2006 Pop_65_yrs_older Access to Clean Water • Provides a limited OR poor explanation	0

c) ACTIVITY – Which map or maps could be used to determine the quality of life for people living in the developing world? Explain

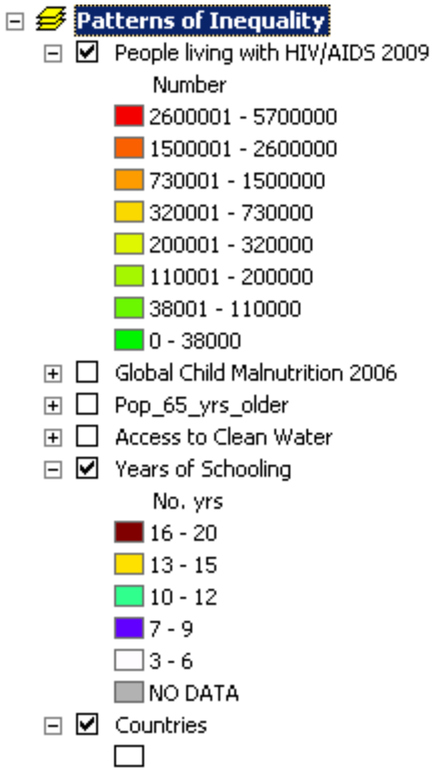
Criteria	Marks
• Student clearly states at least FOUR of the following: People living with HIV/AIDS 2009 Global Child Malnutrition 2006 Pop_65_yrs_older Access to Clean Water • Provides a clear and concise explanation	2
• Student clearly states at least TWO of the following: People living with HIV/AIDS 2009 Global Child Malnutrition 2006 Pop_65_yrs_older Access to Clean Water • Provides a general explanation	1
• Student fails to state EITHER: People living with HIV/AIDS 2009 Global Child Malnutrition 2006 Pop_65_yrs_older Access to Clean Water • Provides a limited OR poor explanation	0

Part D

1 – Click the **Zoom to Full Extent** button  and make sure that the following map layers are expanded and turned ON (checked with a tick).

- **People living with HIV/AIDs 2009**
- **Years of Schooling**

The layers to left should look like this



2 – From the **Effects** dropdown menu, select **People living with HIV/AIDS 2009**

Click on the **Swipe** tool 

Click your mouse on the top of the screen and then drag the swipe tool down the screen. You should see the different layers.

a) ACTIVITY – Describe any patterns that you see between People living with HIV/AIDS (%) AND Yrs of Schooling (No. of yrs)

Criteria	Marks
• Student clearly and accurately refers to BOTH HIV/AIDS and Yrs of Schooling: - Countries in Nth America, Sth Central Africa, India and Russia have HIGH levels of HIV/AIDS - Countries like Africa, Central Asia, Nth South America have low levels of schooling AND • Student notes SOME overlap between the two layers and that there is likely to be SOME link between the two BUT not HIV/AIDS occurrence not exclusive to Developing countries as shown by Nth America	3
• Student generally refers to BOTH HIV/AIDS and Yrs of Schooling: - Countries in India and Central and Eastern Africa have HIGH levels of Child Malnutrition - Countries in Africa and Central Asia have POOR access to clean water AND/OR • Student notes SOME overlap between the two layers AND/OR that there is likely to be SOME link between the two • MAY refer to the fact that HIV/AIDS occurrence not exclusive to Developing countries as shown by Nth America	2
• Student makes some reference to EITHER HIV/AIDS OR Yrs of Schooling: - Countries in India and Central and Eastern Africa have HIGH levels of Child Malnutrition - Countries in Africa and Central Asia have POOR access to clean water OR • Student notes SOME overlap between the two layers AND/OR that there is likely to be SOME link between the two • MAY make some to the fact that HIV/AIDS occurrence not exclusive to Developing countries as shown by Nth America	1

• Student makes no reference to any connection between the two layers AND/OR incorrectly identifies areas of HIV/AIDS and Yrs of Schooling	0

b) ACTIVITY – Explain reasons for any patterns that you see.

Criteria	Marks
• Student makes a clear and distinct reference to the fact that: - There is some correlation between HIV/AIDS OR Yrs of Schooling BUT it is not exclusive AND - countries with HIGH HIV/AIDS is most likely developing and therefore access to schooling is poor in these countries	3
• Student makes a general reference to the fact that: - There is some correlation between HIV/AIDS OR Yrs of Schooling BUT it is not exclusive AND - countries with HIGH HIV/AIDS is most likely developing and therefore access to schooling is poor in these countries	2
• Student makes some reference to the fact that: - There is some correlation between HIV/AIDS OR Yrs of Schooling BUT it is not exclusive AND - countries with HIGH HIV/AIDS is most likely developing and therefore access to schooling is poor in these countries	1
• Student makes NO general reference to the fact that: - There is some correlation between HIV/AIDS OR Yrs of Schooling BUT it is not exclusive OR - countries with HIGH HIV/AIDS is most likely developing and therefore access to schooling is poor in these countries	0

Part E

a) ACTIVITY – If you were a member of an Aid Organisation whose responsibility it was to help people in a developing country, explain THREE things that would you do to improve the standard of living for the people (in rank order)?

Criteria	Marks
• Student accurately interprets the activity and thoughtfully identifies THREE things that they would do to improve the standard of living for people in a developing country • Clearly explains how they would improve the quality of life for the family • The writing demonstrates a high level of understanding of the activity and provides a clear and concise response	3
• Student interprets the activity and identifies THREE things that they would do to improve the standard of living for people in a developing country • Generally, explains how they would improve the quality of life for the family • The writing demonstrates a general level of understanding of the activity and provides a clear and concise response	2
• Student interprets the activity and identifies LESS than THREE things that they would do to improve the standard of living for people in a developing country • Generally, explains how they would improve the quality of life for the family • The writing demonstrates some understanding of the activity and provides a clear and concise response	1
• Student identifies LESS than THREE things that they would do to improve the standard of living for people in a developing country • Provides a limited explanation of how they would improve the quality of life for the family • The writing demonstrates limited understanding of the activity and provides a poor response	0

Part F

a) ACTIVITY – You work for the United Nations and have an excellent knowledge and understanding of inequalities that exist between countries of the developed and developing world.

You have been asked to create a new index for determining whether a country is wealthy or poor.

Use your knowledge to create the new measure and explain the reasoning that you used to produce the index.

Criteria	Marks
• Student accurately interprets the activity and thoughtfully provides a unique new index for determining whether a country is wealthy or poor • Clearly explains the index and distinctly describes the theory behind its development • The writing demonstrates a high level of understanding of the activity and provides a clear and concise response	4
• Student interprets the activity and provides a unique new index for determining whether a country is wealthy or poor • Provides a general explanation of the index and describes the theory behind its development • The writing demonstrates a good level of understanding of the activity and provides a clear and concise response	3
• Student shows some evidence of interpreting the activity and provides a general index for determining whether a country is wealthy or poor • Provides some explanation of the index AND/OR describes the theory behind its development • The writing demonstrates a general level of understanding of the activity and provides a general response	2
• Student shows limited evidence of having interpreted the activity and provides a limited index for determining whether a country is wealthy or poor • Provides a limited explanation of the index AND/OR some reference to the theory behind its development • The writing demonstrates a limited level of understanding of the activity and provides a general response	1
• Student shows NO evidence of having interpreted the activity OR provides NO index for determining whether a country is wealthy or poor • Provides a poor explanation of the index AND/OR poor reference to the theory behind its development • The writing demonstrates a poor level of understanding of the activity and provides a general response	0

ENERGY

PRE-TEST
MARKING CRITERIA

GIS Activity
Year 9

NAME: ____________________________________

GROUP: ____________________

DATE OF BIRTH: _________________________

PRE-TEST

Part A

a) ACTIVITY – What do you understand the following terms to mean?

Fossil Fuel: Fossil Fuels are non-renewable resources that are formed by natural processes and are derived from dead plant and animal material. They are formed due to anaerobic decomposition under intense heat and pressure.

Criteria	Marks
• Student demonstrates a clear understanding of **fossil fuels** by providing a detailed and accurate description of the term	2
• Student demonstrates some understanding of **fossil fuels** by providing a partially accurate description of the term	1
• Student demonstrates no understanding of **fossil fuels** by failing to provide a description of the term OR by providing an inaccurate definition of the term	0

Renewable Energy: is energy that can maintain and/or replace itself if managed carefully.

Criteria	Marks
• Student demonstrates a clear understanding of **renewable energy** by providing a detailed and accurate description of the term	2
• Student demonstrates some understanding of **renewable energy** by providing a partially accurate description of the term	1
• Student demonstrates no understanding of **renewable energy** by failing to provide a description of the term OR by providing an inaccurate definition of the term	0

Sustainable Resource Use: involves using resources wisely today so that people in the future can still use them

Criteria	Marks
• Student demonstrates a clear understanding of **sustainable resource use** by providing a detailed and accurate description of the term	2
• Student demonstrates some understanding of **sustainable resource use** by providing a partially accurate description of the term	1
• Student demonstrates no understanding of **sustainable resource use** by failing to provide a description of the term OR by providing an inaccurate definition of the term	0

Gross Domestic Product: refers to the total value of all goods and services produced within a country in a given period.

Criteria	Marks
• Student demonstrates a clear understanding of **gross domestic product** by providing a detailed and accurate description of the term	2
• Student demonstrates some understanding of **gross domestic product** by providing a partially accurate description of the term	1
• Student demonstrates no understanding of **gross domestic product** by failing to provide a description of the term OR by providing an inaccurate definition of the term	0

Part B

a) ACTIVITY – Explain what the following cartoon is suggesting

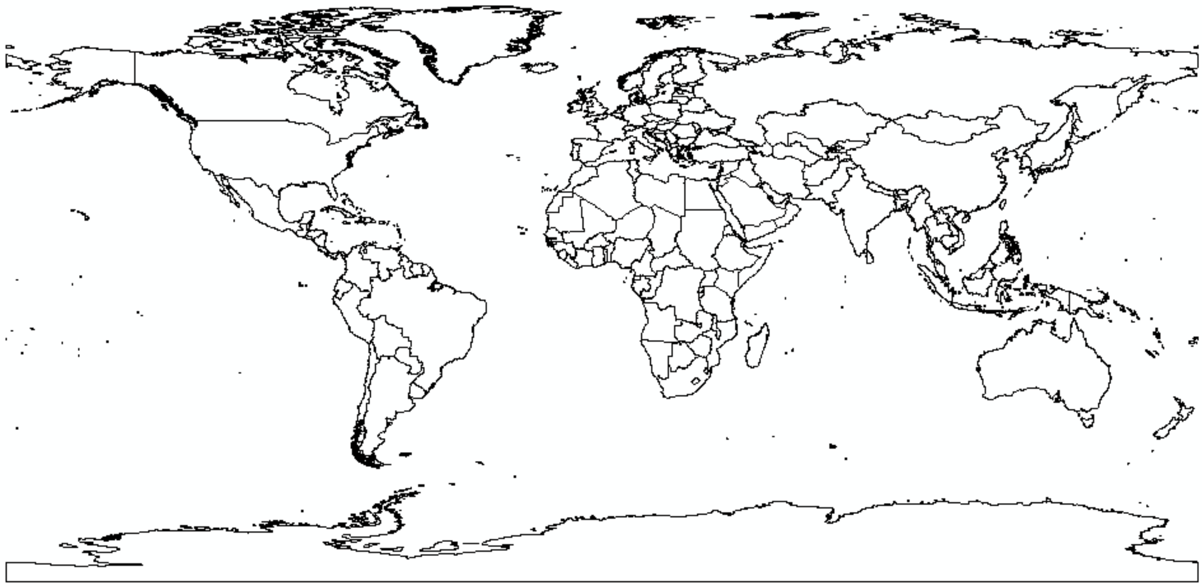
Criteria	Marks
• Student provides accurate and clear reference to the meaning of the cartoon • Makes particular reference to the US's insatiable appetite for foreign oil to fuel its significant energy needs	3
• Student provides general reference to the meaning of the cartoon • Makes general reference to the US's insatiable appetite for foreign oil to fuel its significant energy needs	2
• Student provides limited reference to the meaning of the cartoon OR • Makes limited reference to the US's insatiable appetite for foreign oil to fuel its significant energy needs	1
• Student provides NO accurate reference to the meaning of the cartoon	0

b) ACTIVITY – On the map below, indicate (by shading generally) the countries of the world that have a large INDUSTRIAL based economy.

Criteria	Marks
• Student demonstrates a clear knowledge of countries that have a large industrial based economy by correctly shading FOUR or more countries/continents including North America, China, Australia, Japan, UK, Western Europe etc	3
• Student demonstrates some knowledge of countries that have a large industrial based economy by correctly shading TWO to FOUR countries/continents including North America, China, Australia, Japan, UK, Western Europe etc	2
• Student demonstrates limited knowledge of countries that have a large industrial based economy by correctly shading LESS than TWO countries/continents including North America, China, Australia, Japan, UK, Western Europe etc	1
• Student demonstrates NO knowledge of countries that have a large industrial based economy by failing to shade any country correctly	0

Part C

ArcMap should be open on the computer with the following displayed



Explore the different map layers on the left-hand side by turning them ON and OFF. You should expand the layers also by clicking your mouse on the plus (+) sign.

a) ACTIVITY – Which map layer/s could be used to determine whether a country produces fossil fuels? Explain

Criteria	**Marks**
• Student clearly states TWO of the following: Oil Production Coal Production Gas Production • Student clearly explains their answer	2
• Student clearly states at least ONE of the following: Oil Production Coal Production Gas Production • Student generally explains their answer	1
• Student fails to state ONE of the following: Oil Production Coal Production Gas Production • Student provides a limited explanation	0

b) ACTIVITY – Which map layer/s could be used to determine whether a country has a strong AGRICULTURAL based economy? Explain

Criteria	Marks
• Student clearly states the following: % GDP in Agriculture AND • Provides a clear and concise explanation	2
• Student clearly states the following: % GDP in Agriculture AND/OR • Provides a general explanation	1
• Student FAILS to state the following: % GDP in Agriculture OR • Provides general explanation	0

c) ACTIVITY – If a country has an INDUSTRY based economy, would you expect that they would consume a lot of fossil fuels? Explain

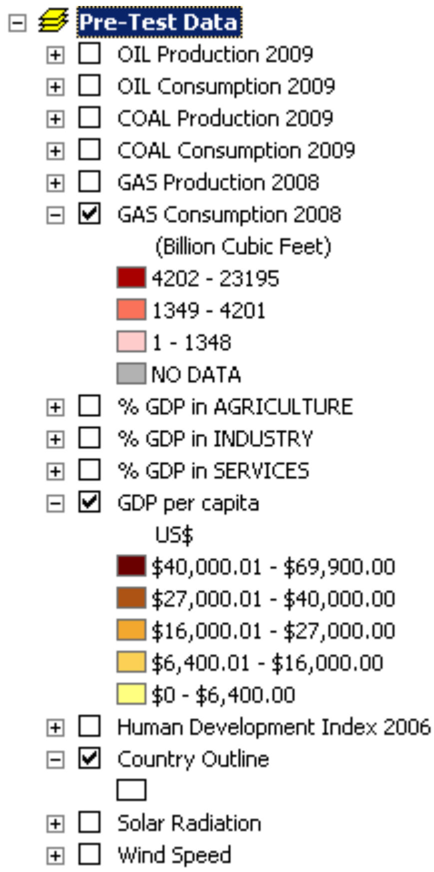
Criteria	Marks
• Student provides a clear response (YES) AND a clear explanation that countries with industry based economies require large amounts of fossil fuels for their large industries.	2
• Student provides a clear response (YES) AND a general explanation that countries with industry based economies require large amounts of fossil fuels for their large industries.	1
• Student provides a clear response (YES) AND/OR a limited explanation that countries with industry based economies require large amounts of fossil fuels for their large industries.	0

Part D

1 – Click the **Zoom to Full Extent** button  and make sure that the following map layers are expanded and turned ON (checked with a tick).

- **Gas Consumption 2008**
- **GDP per Capita**

The layers to left should look like this



2 – From the **Effects** dropdown menu, select **GAS Consumption 2008**

Click on the **Flicker** tool 

Click on the **Flicker** tool to stop the layers flickering

a) ACTIVITY – Explain any relationship that you see between Gas Consumption and GDP per capita?

Criteria	Marks
• Student clearly and accurately refers to BOTH Gas Consumption and GDP per capita and notes that Countries in North America, Europe and China have both high levels of Gas consumption and GDP per capita AND • Student notes the overlap between the two layers and that there is likely to be a strong link between the two layers	3
• Student generally refers to BOTH Gas Consumption and GDP per capita and notes that Countries in North America, Europe and China have both high levels of Gas consumption and GDP per capita AND • Student notes the overlap between the two layers and that there is likely to be a general between the two layers	2
• Student makes some reference to EITHER Gas Consumption OR GDP per capita and notes that Countries in North America, Europe and China have both high levels of Gas consumption and GDP per capita OR • Student notes the overlap between the two layers and that there is likely to be a some between the two layers	1
• Student makes no reference to any connection between the two layers AND/OR incorrectly identifies areas of Gas Consumption OR GDP per capita	0

Part E

Read the following and complete the activities below:
*You work for the **Alternative Energy Company (AEC)** which is an organisation that helps African countries to adopt new energy sources and technologies.*

*You have recently returned from the country of Chad in Central Africa (shown below) where you were employed by the **Minister of Energy** to investigate alternative energy sources for the country. The Minister is hoping to convince the Prime Minister to adopt new energy sources that are cheaper but have not yet been considered.*

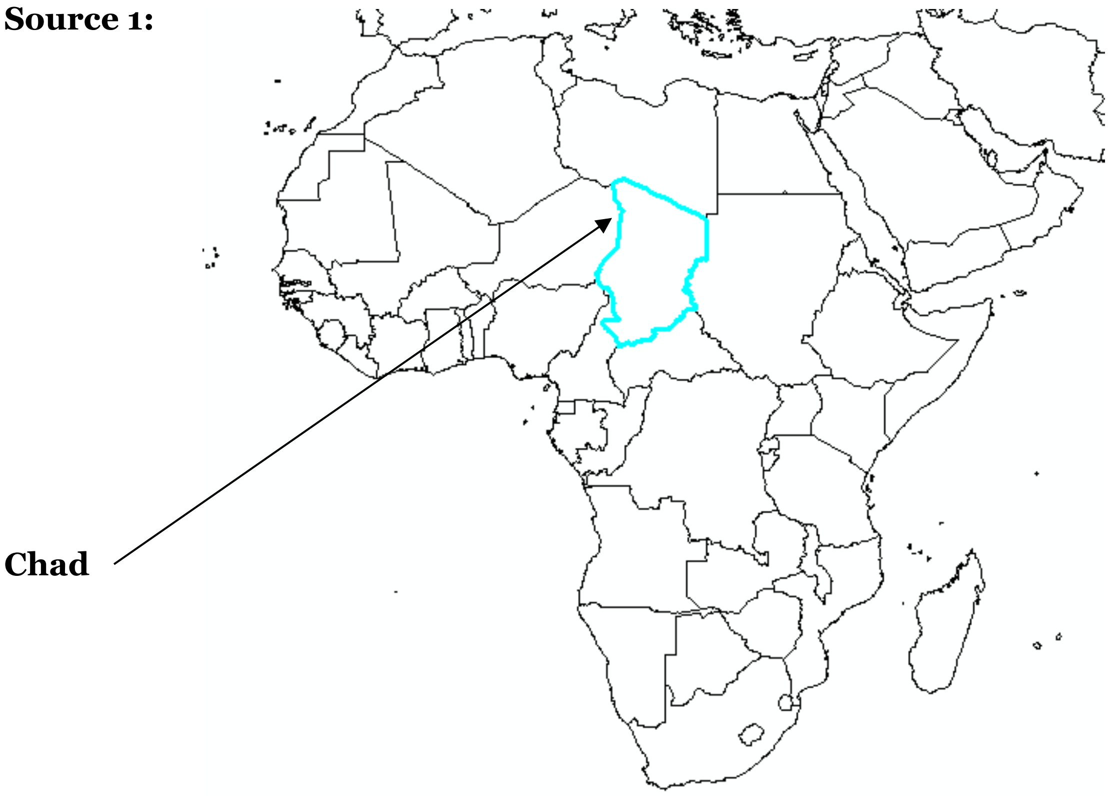
The Minister is relying on your final report to help convince the Prime Minister to make the change to alternative energy solutions.

a) ACTIVITY – You need to examine the source material and:

i. Explain why renewable energy resources should be considered by Chad due to their current economic situation

ii. Identify ONE alternative energy source and explain why you have chosen it.

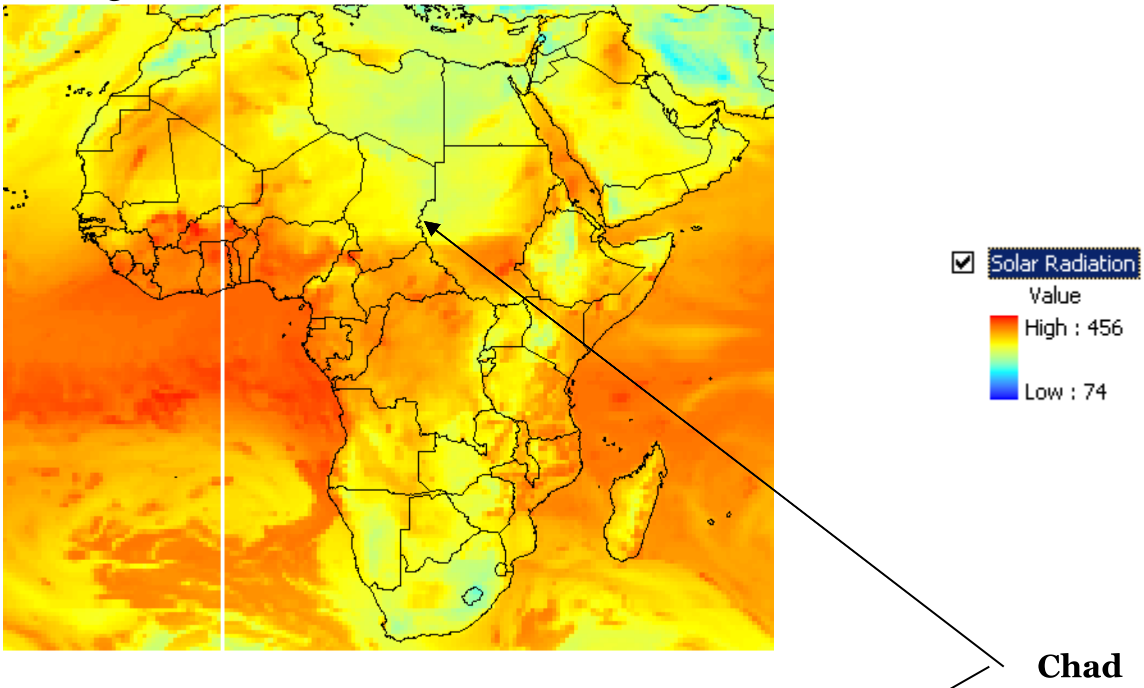
Source 1:



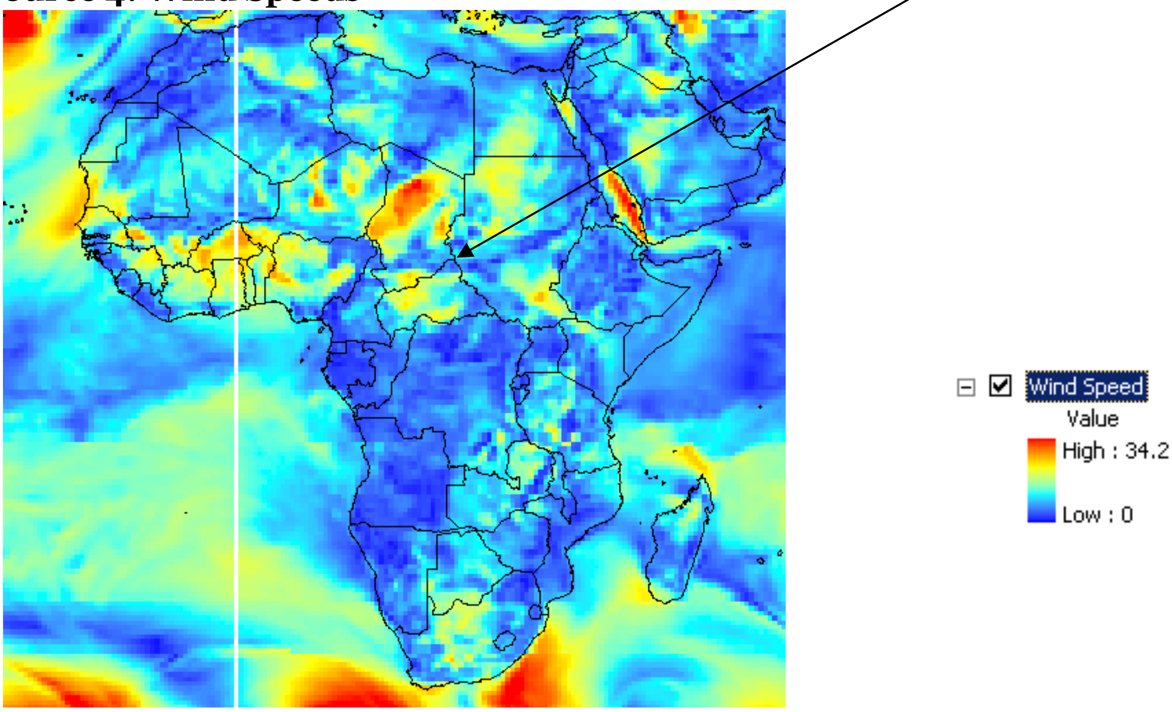
Source 2: Chad's Economical Statistics

% Contribution of GDP	
AGRICULTURE	32.5 %
INDUSTRY	26.6 %
SERVICES	40.8%

Source 3: Solar Radiation



Source 4: Wind Speeds



iii. ACTIVITY – Explain why renewable energy resources should be considered by Chad considering their current economic situation

Criteria	Marks
• Student accurately interprets the activity and thoughtfully explains why renewable energy resources should be considered by Chad considering their current economic situation • Student accurately refers too and uses at least THREE pieces of Source material • The writing demonstrates a high level of understanding of the activity and provides a clear and concise response	3
• Student interprets the activity and thoughtfully explains why renewable energy resources should be considered by Chad considering their current economic situation • Student generally refers too and uses at least TWO pieces of Source material • The writing demonstrates a good level of understanding of the activity and provides a clear and concise response	2
• Student provides some interpretation of the activity and attempts to explain why renewable energy resources should be considered by Chad considering their current economic situation • Student provides limited reference to and uses at least ONE piece of Source material • The writing demonstrates a general level of understanding of the activity and provides a clear and concise response	1
• Student provides little OR no interpretation of the activity AND fails to explain why renewable energy resources should be considered by Chad considering their current economic situation • Student provides little OR no reference to OR uses any pieces of Source material • The writing demonstrates a poor level of understanding of the activity	0

iv. ACTIVITY – Identify ONE alternative energy source and explain why you have chosen it.

Criteria	Marks
• Student accurately identifies ONE alternative energy source AND refers to Source 3 and 4 in their response • Student provides a thoughtful and accurate explanation as to why it should be used • The writing demonstrates a high level of understanding of the activity and provides a clear and concise response	3
• Student identifies ONE alternative energy source AND/OR refers to EITHER Source 3 and 4 in their response • Student provides a general explanation as to why it should be used • The writing demonstrates a general level of understanding of the activity and provides a general response	2
• Student identifies ONE alternative energy source and MAY or MAY NOT refers to EITHER Source 3 OR 4 in their response • Student provides a limited explanation as to why it should be used • The writing demonstrates a limited level of understanding of the activity and provides a limited response	1
• Student fails to identify ONE alternative energy source AND fails to refer to EITHER Source 3 OR 4 in their response • Student provides a poor or nil explanation as to why it should be used • The writing demonstrates a poor level of understanding of the activity	0

Part F

*Imagine it is the future and you live in a highly **developed** (wealthy) nation. You are also the **Energy/Resources Minister** in the government and responsible for ensuring that the country's economy continues to grow strongly.*

*Unfortunately, fossil fuels are diminishing and there is pressure to move towards **renewable energy sources**. With an election approaching and concerns about the environment growing, public support for your government is diminishing and swinging to the **Environmental Political Party.** Their policies support the use of sustainable and renewable energy resources.*

a) ACTIVITY – your task is to devise a new strategy that your government can take to the next election. You must identify and THREE key strategies that your government will adopt and explain why you have chosen them (in rank order).

Criteria	Marks
• Student accurately interprets the activity and accurately devises a new strategy that your government can take to the next election • Student clearly identifies THREE key strategies • Provides a thoughtful and clear explanation • The writing demonstrates a high level of understanding of the activity and provides a clear and concise response	3
• Student generally interprets the activity and devises a new strategy that your government can take to the next election • Student generally identifies THREE key strategies • Provides a generally clear explanation • The writing demonstrates a general level of understanding of the activity and provides a clear and concise response	2
• Student shows some ability to interpret the activity and devise a new strategy that your government can take to the next election • Student generally identifies ONE to THREE key strategies • Provides a limited explanation • The writing demonstrates a limited understanding of the activity and provides a limited response	1
• Student fails to interpret the activity OR devise a new strategy that your government can take to the next election • Student fails to identify any key strategies • May provide a poor explanation • The writing demonstrates a poor understanding of the activity	0

ENERGY

<u>POST-TEST</u>
<u>MARKING CRITERIA</u>

GIS Activity
Year 9

NAME: ______________________________________

GROUP: ______________________

DATE OF BIRTH: ___________________________

PRE-TEST

Part A

a) ACTIVITY – What do you understand the following terms to mean?

Fossil Fuel: Fossil Fuels are non-renewable resources that are formed by natural processes and are derived from dead plant and animal material. They are formed due to anaerobic decomposition under intense heat and pressure.

Criteria	Marks
• Student demonstrates a clear understanding of **fossil fuels** by providing a detailed and accurate description of the term	2
• Student demonstrates some understanding of **fossil fuels** by providing a partially accurate description of the term	1
• Student demonstrates no understanding of **fossil fuels** by failing to provide a description of the term OR by providing an inaccurate definition of the term	0

Renewable Energy: is energy that can maintain and/or replace itself if managed carefully.

Criteria	Marks
• Student demonstrates a clear understanding of **renewable energy** by providing a detailed and accurate description of the term	2
• Student demonstrates some understanding of **renewable energy** by providing a partially accurate description of the term	1
• Student demonstrates no understanding of **renewable energy** by failing to provide a description of the term OR by providing an inaccurate definition of the term	0

Industrialised Nation: may refer to a developed country, however, it is more likely a country that has a strong industry or manufacturing sector, large national corporations operating in different continents and strong capital investment

Criteria	Marks
• Student demonstrates a clear understanding of **industrialised nation** by providing a detailed and accurate description of the term	2
• Student demonstrates some understanding of **industrialised nation** by providing a partially accurate description of the term	1
• Student demonstrates no understanding of **industrialised nation** by failing to provide a description of the term OR by providing an inaccurate definition of the term	0

Developed World: includes Australia, New Zealand, Japan, Canada, the United States and the countries of Western Europe. These countries have high levels of industrial development and most of the population enjoys a high standard of living

Criteria	Marks
• Student demonstrates a clear understanding of **developed world** by providing a detailed and accurate description of the term	2
• Student demonstrates some understanding of **developed world** by providing a partially accurate description of the term	1
• Student demonstrates no understanding of **developed world** by failing to provide a description of the term OR by providing an inaccurate definition of the term	0

Part B

a) ACTIVITY – Explain what the following image is suggesting

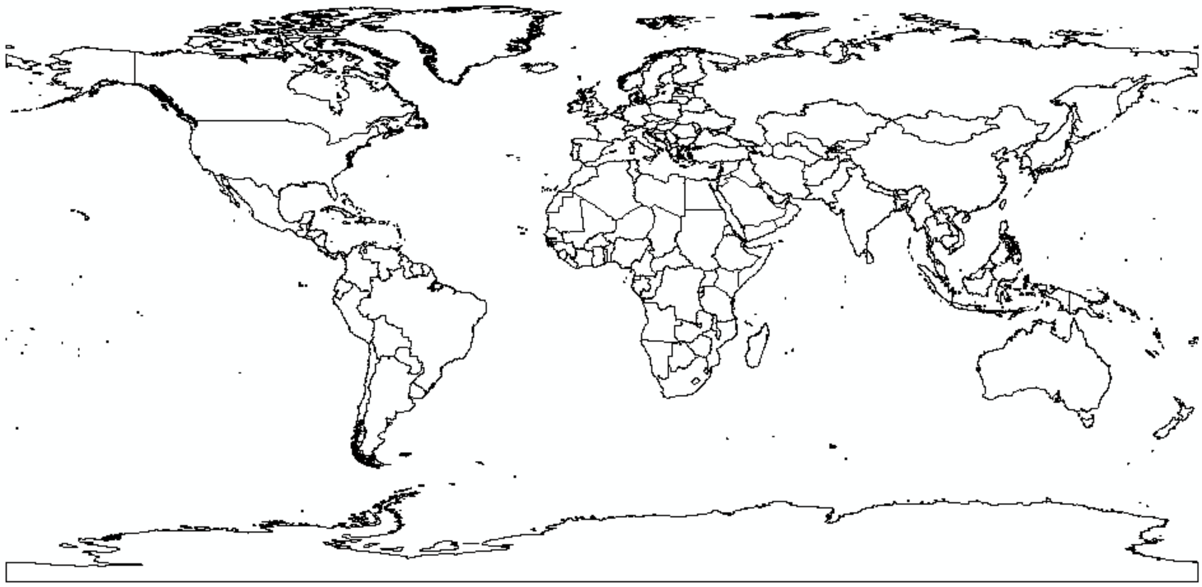
Criteria	Marks
• Student provides accurate and clear reference to the meaning of the cartoon • Makes particular reference to the need of both United States and China for foreign oil to fuel their respective significant energy needs	3
• Student provides general reference to the meaning of the cartoon • Makes general reference to the need of both United States and China for foreign oil to fuel their respective significant energy needs	2
• Student provides limited reference to the meaning of the cartoon OR • Makes limited reference to the need of the United States and China for foreign oil to fuel their respective significant energy needs	1
• Student provides NO accurate reference to the meaning of the cartoon	0

b) ***ACTIVITY – On the map below, indicate (by shading generally) the countries of the world that have a large SERVICE based economy.***

Criteria	Marks
• Student demonstrates a clear knowledge of countries that have a large industrial based economy by correctly shading FOUR or more countries/continents including North America, Australia, Japan, UK, Western Europe etc	3
• Student demonstrates some knowledge of countries that have a large industrial based economy by correctly shading TWO to FOUR countries/continents including North America, Australia, Japan, UK, Western Europe etc	2
• Student demonstrates limited knowledge of countries that have a large industrial based economy by correctly shading LESS than TWO countries/continents including North America, Australia, Japan, UK, Western Europe etc	1
• Student demonstrates NO knowledge of countries that have a large industrial based economy by failing to shade any country correctly	0

Part C

ArcMap should be open on the computer with the following displayed



Explore the different map layers on the left-hand side by turning them ON and OFF. You should expand the layers also by clicking your mouse on the plus (+) sign.

a) ACTIVITY – Which map layer/s could be used to determine whether a country consumes fossil fuels? Explain

Criteria	Marks
• Student clearly states TWO of the following: Oil Consumption Coal Consumption Gas Consumption	2
• Student clearly states at least ONE of the following: Oil Consumption Coal Consumption Gas Consumption	1
• Student fails to state ONE of the following: Oil Consumption Coal Consumption Gas Consumption	0

b) ACTIVITY – Which map layer/s could be used to determine whether a country has a strong SERVICE based economy? Explain

Criteria	Marks
• Student clearly states TWO of the following: % GDP in Services • Student clearly explains their answer	2
• Student clearly states at least ONE of the following: Oil Consumption Coal Consumption Gas Consumption • Student generally explains their answer	1
• Student fails to state ONE of the following: Oil Consumption Coal Consumption Gas Consumption • Student provides a limited explanation	0

c) ACTIVITY – If a country has an AGRICULTURAL based economy, would you expect that they would consume a lot of fossil fuels? Explain

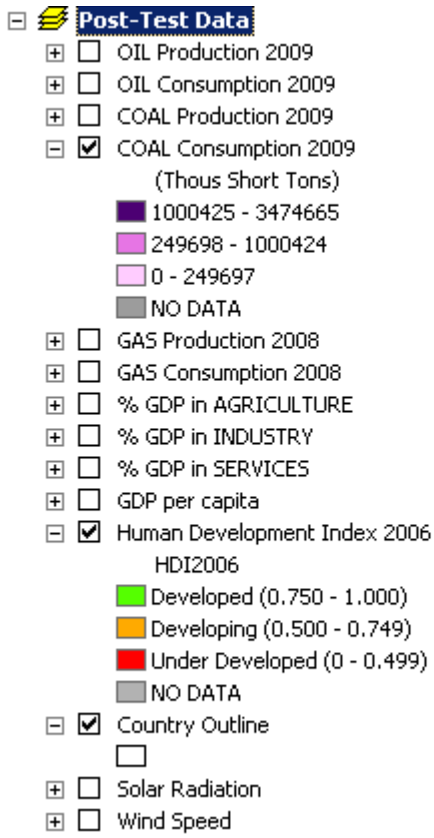
Criteria	Marks
• Student provides a clear response (YES) AND a clear explanation that countries with agricultural based economies do not traditionally have large industrialised economies • May also suggest that the economy is developing	2
• Student provides a clear response (YES) AND a general explanation that countries with agricultural based economies do not traditionally have large industrialised economies • May also suggest that the economy is developing	1
• Student provides a clear response (YES) AND/IO a limited explanation that countries with agricultural based economies do not traditionally have large industrialised economies	0

Part D

1 – Click the **Zoom to Full Extent** button  and make sure that the following map layers are expanded and turned ON (checked with a tick).

- **Coal Consumption 2008**
- **Human Development Index 2006**

The layers to left should look like this



2 – From the **Effects** dropdown menu, select **Coal Consumption 2008**

Click on the **Flicker** tool 

Click on the **Flicker** tool to stop the layers flickering

a) ACTIVITY – Explain any relationship that you see between Coal Consumption 2009 and Human Development Index 2006?

<table>
<tr><th>Criteria</th><th>Marks</th></tr>
<tr><td>Student clearly and accurately refers to BOTH Coal Consumption and Human Development Index and notes that Countries with high Coal Consumption (Nth America, Western Europe, Australia, China) have high Development Index value
AND
Student notes the overlap between the two layers and that there is likely to be a strong link between the two layers</td><td>3</td></tr>
<tr><td>Student generally refers to BOTH Gas Consumption and GDP per capita and notes that Countries with high Coal Consumption (Nth America, Western Europe, Australia, China) have high Development Index value
AND
Student notes the overlap between the two layers and that there is likely to be a general between the two layers</td><td>2</td></tr>
<tr><td>Student makes some reference to EITHER Gas Consumption OR GDP per capita and notes that Countries with high Coal Consumption (Nth America, Western Europe, Australia, China) have high Development Index value
OR
Student notes the overlap between the two layers and that there is likely to be a some between the two layers</td><td>1</td></tr>
<tr><td>Student makes no reference to any connection between the two layers AND/OR incorrectly identifies areas of Coal Consumption OR Human Development Index</td><td>0</td></tr>
</table>

Part E

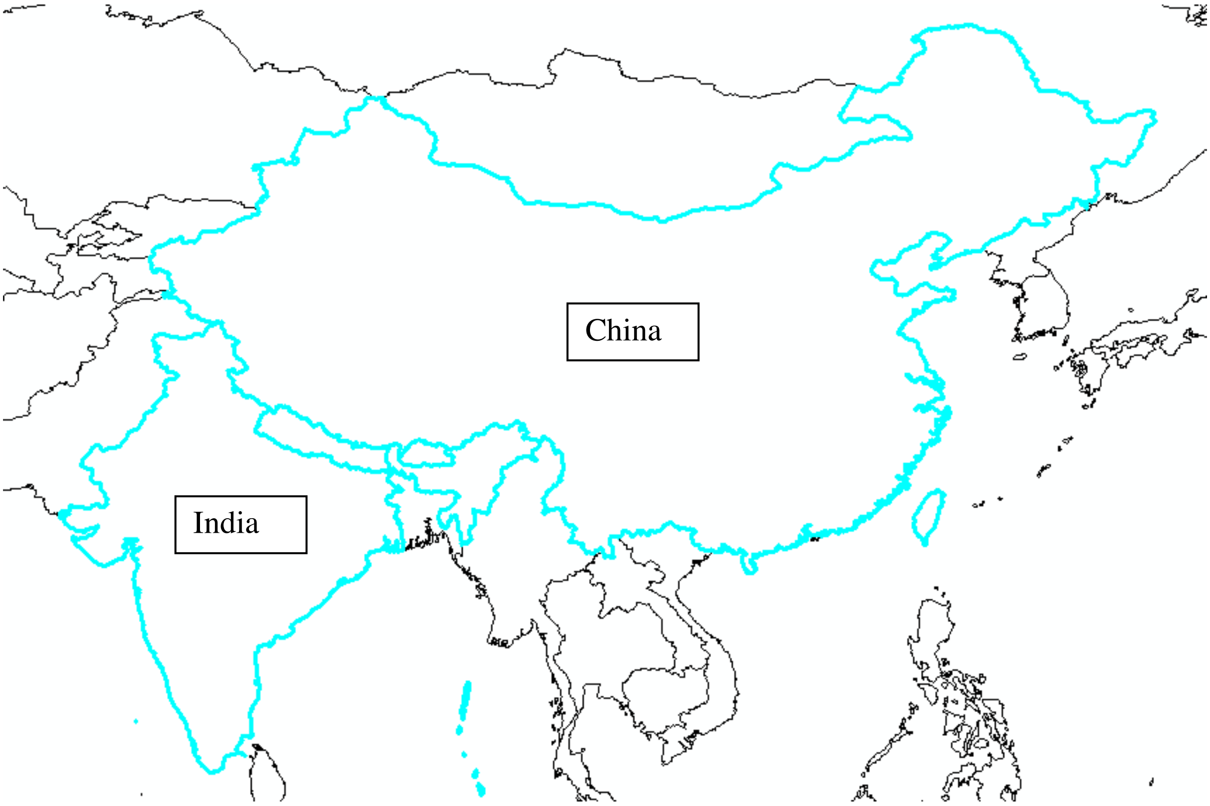
Read the following and complete the activities below:
*The United Nations has decided to donate a large amount of money to ONE country who invests in one or more **large scale** renewable energy projects.*

The selected country must have suitable conditions for large scale (widespread) Wind and Solar projects to be built and they must be widespread. Applications from developing countries will also be considered favourably but the country must have a strong economy. While a strong industry is important, the country must have a strong service sector to manage the project.

China and India have both submitted applications. As an employee of the United Nations, you are required to evaluate both applications. Your job is to decide which country has the most potential to develop a renewable energy program on a large or widespread scale. Your decision must be supported by a suitable justification or explanation.

a) ***ACTIVITY – You need to examine the source material and decide which country has the most potential to develop a renewable energy program on a large scale. Explain with reasons why.***

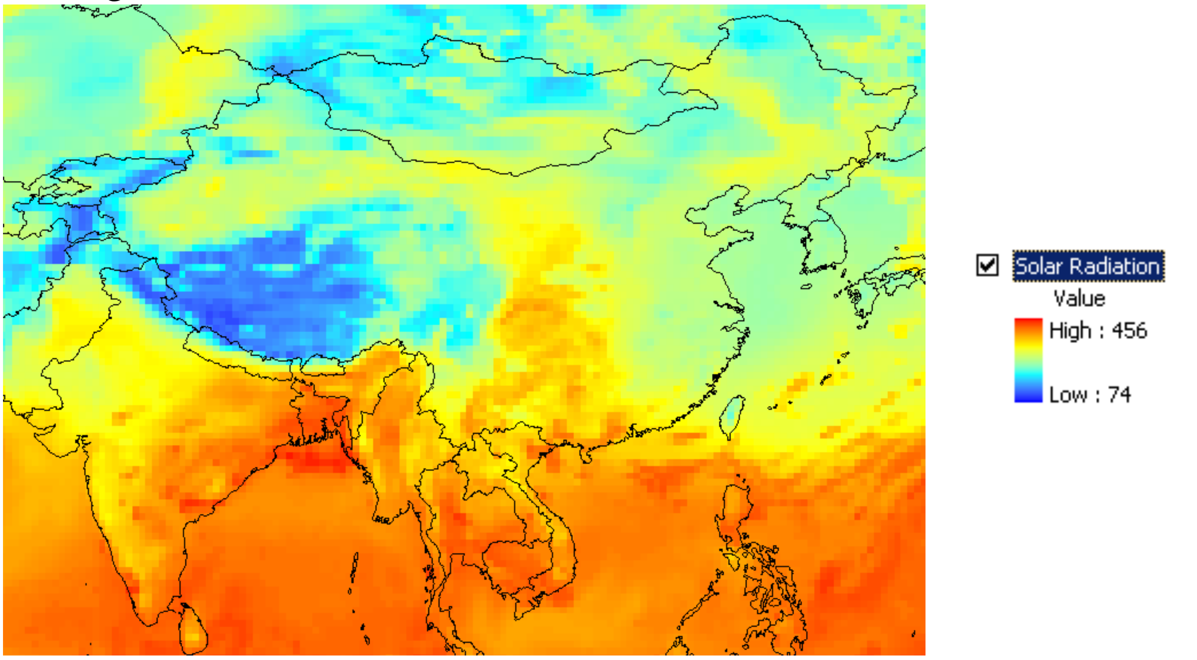
Source 1:



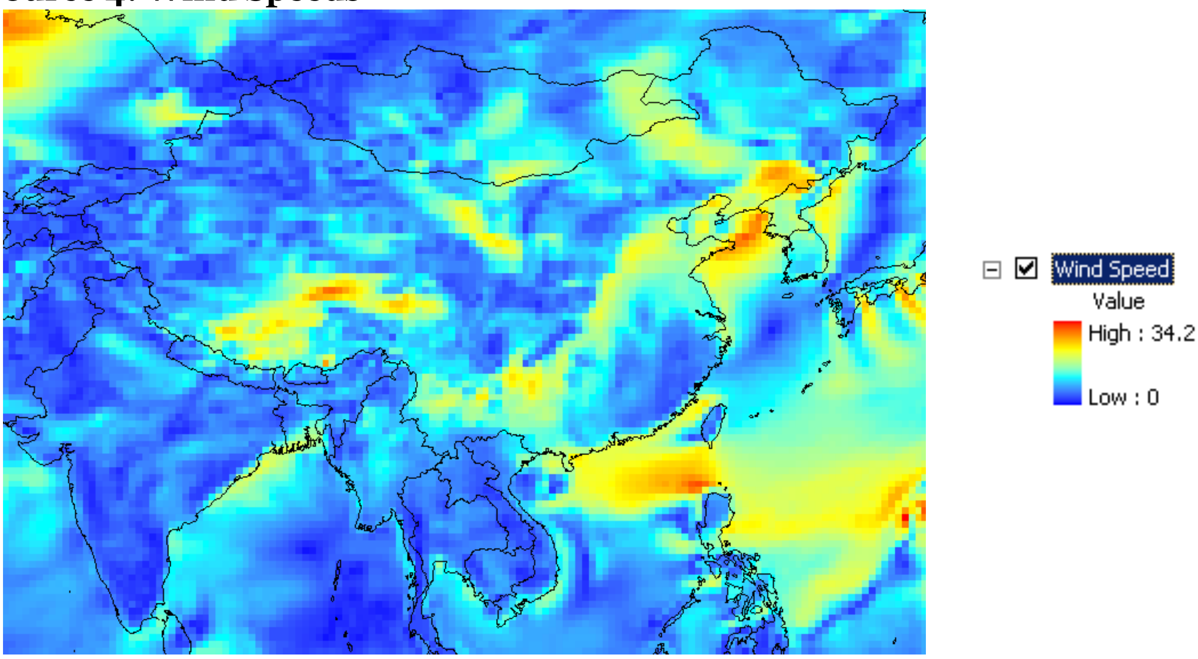
Source 2: Economical Statistics for each country

INDIA		CHINA	
% Contribution of GDP		% Contribution of GDP	
AGRICULTURE	19.9 %	AGRICULTURE	11.9 %
INDUSTRY	19.3 %	INDUSTRY	48.1 %
SERVICES	60.7%	SERVICES	40%

Source 3: Solar Radiation



Source 4: Wind Speeds



Your Evaluation ______________________________

<table>
<tr><th>Criteria</th><th>Marks</th></tr>
<tr><td>Student accurately interprets the activity and clearly identifies the country that has the most potential to develop a renewable energy program (China – both Solar and Wind)
Shows clear evidence of source evaluation by referring to the source material
Student accurately refers too and uses at least THREE pieces of Source material
The writing demonstrates a high level of understanding of the activity and provides a clear and concise response</td><td>3</td></tr>
<tr><td>Student interprets the activity and identifies the country that has the most potential to develop a renewable energy program (China – both Solar and Wind)
Shows evidence of source evaluation by referring to the source material
Student refers too and uses at least TWO pieces of Source material
The writing demonstrates a good understanding of the activity and provides a good response</td><td>2</td></tr>
<tr><td>Student generally interprets the activity and identifies a country that has the most potential to develop a renewable energy program (China – both Solar and Wind)
Shows limited evidence of source evaluation by referring to the source material
Student refers too and uses at least ONE pieces of Source material
The writing demonstrates a limited understanding of the activity and provides a limited response</td><td>1</td></tr>
<tr><td>Student provides little OR no interpretation of the activity AND fails to identifies a country that has the most potential to develop a renewable energy program (China – both Solar and Wind)
Shows NO evidence of source evaluation
The writing demonstrates a poor level of understanding of the activity</td><td>0</td></tr>
</table>

Part F

Imagine it is the future and you live in a highly ***developed*** *(wealthy) nation. You are also the* ***Energy/Resources Minister*** *in the government and responsible for ensuring that the country's economy continues to grow strongly.*

Unfortunately, fossil fuels are diminishing and there is pressure to move towards ***renewable energy sources****. With an election approaching and concerns about the environment growing, public support for your government is diminishing and swinging towards the* ***Environmental Political Party.*** *Their policies support the use of sustainable and renewable energy resources.*

a) ACTIVITY – your task is to devise a new strategy that your government can take to the next election. You must identify and THREE key strategies that your government will adopt and explain why you have chosen them (in rank order i.e.: 1 Top Priority etc).

Criteria	Marks
• Student accurately interprets the activity and accurately devises a new strategy that your government can take to the next election • Student clearly identifies THREE key strategies • Provides a thoughtful and clear explanation • The writing demonstrates a high level of understanding of the activity and provides a clear and concise response	5-6
• Student generally interprets the activity and devises a new strategy that your government can take to the next election • Student generally identifies THREE key strategies • Provides a generally clear explanation • The writing demonstrates a general level of understanding of the activity and provides a clear and concise response	3-4
• Student shows some ability to interpret the activity and devise a new strategy that your government can take to the next election • Student generally identifies ONE to THREE key strategies • Provides a limited explanation • The writing demonstrates a limited understanding of the activity and provides a limited response	1-2
• Student fails to interpret the activity OR devise a new strategy that your government can take to the next election • Student fails to identify any key strategies • May provide a poor explanation • The writing demonstrates a poor understanding of the activity	0

Appendix D: Open-ended Post-Test Survey Questions

1. What did you like about the lesson?
2. What didn't you like about the lesson?
3. Do you have any other comments about the lesson?
4. In your opinion, how do you think this lesson could have been improved to help you better understand the topic of development OR energy?
5. How do you think the GIS could have been used more effectively to help you understand the topic of development OR energy?

Appendix E: Focus Group Questions

1 – Can you identify and explain the differences between the lesson types that you experienced?

2 – What features of the lesson did you OR did you not enjoy about the lesson?

3 – What comments can you make about the teacher's role during the lesson?

4 – What did you enjoy the most about using GIS in this lesson?

5 – What did you enjoy the least about using GIS in this lesson?

6 – What do you think helped you to understand the lesson the most during the lesson?

7 – How do you think the lesson could have been improved?

8 – What is your opinion on using technologies like GIS in Geography lessons?

9 – What do you think was the most important thing that you gained from using GIS during the lesson?

10 - Do you feel that GIS helped you to think more about the <topic> during the lesson? Explain.

11 – How do you think GIS could have been used more effectively to help you understand the <topic> you were studying?

Appendix F: Tests for normality

Intervention 1:

TEST 1 - NORMALITY TESTS (Gp I vs Gp II combined pre-test scores)			
Gp I	Gp II	Gp I	Gp II
dist1skewness/dist1standarderror	dist2skewness/dist2standarderror	dist1kurtosis/dist1standarderror	dist2kurtosis/dist2standarderror
-0.239656539	0.228190616	-0.049622503	-0.351519945

TEST 2 - NORMALITY TESTS (Dev VS Energy improve scores)			
DEV improve	ENER improve	DEV improve	ENER improve
dist1skewness/dist1standarderror	dist2skewness/dist2standarderror	dist1kurtosis/dist1standarderror	dist2kurtosis/dist2standarderror
0.015124532	0.387356291	-0.517440141	-0.622310889

TEST 3 - NORMALITY TESTS (using DI and GD improve scores)			
DI improve	GD improve	DI improve	GD improve
dist1skewness/dist1standarderror	dist2skewness/dist2standarderror	dist1kurtosis/dist1standarderror	dist2kurtosis/dist2standarderror
0.327416572	0.06378349	-0.274238404	-0.316991153

TEST 4 - NORMALITY TESTS (using LOT Pre-Post Test improve scores)			
LOT Pre-Test	LOT Post-Test	LOT Pre-Test	LOT Post-Test
dist1skewness/dist1standarderror	dist2skewness/dist2standarderror	dist1kurtosis/dist1standarderror	dist2kurtosis/dist2standarderror
0.025199415	-1.089114625	-0.157364145	1.787404659

TEST 5 - NORMALITY TESTS (using HOT Pre-Post Test improve scores)			
HOT Pre-Test	HOT Post-Test	HOT Pre-Test	HOT Post-Test
dist1skewness/dist1standarderror	dist2skewness/dist2standarderror	dist1kurtosis/dist1standarderror	dist2kurtosis/dist2standarderror
-0.161578576	0.544853743	-0.61688396	-0.40415123

Intervention 2:

TEST 1 - NORMALITY TESTS (Gp I vs Gp II combined pre-test scores)			
Gp I	Gp II	Gp I	Gp II
dist1skewness/dist1standarderror	dist2skewness/dist2standarderror	dist1kurtosis/dist1standarderror	dist2kurtosis/dist2standarderror
0.095863565	-0.061586385	0.129763151	1.024911835

TEST 2 - NORMALITY TESTS (Dev VS Energy improve scores)			
DEV improve	ENER improve	DEV improve	ENER improve
dist1skewness/dist1standarderror	dist2skewness/dist2standarderror	dist1kurtosis/dist1standarderror	dist2kurtosis/dist2standarderror
-0.188695942	0.521796623	-0.464707155	-0.939630689

TEST 3 - NORMALITY TESTS (DI vs GD improve scores)			
DI improve	GD improve	DI improve	GD improve
dist1skewness/dist1standarderror	dist2skewness/dist2standarderror	dist1kurtosis/dist1standarderror	dist2kurtosis/dist2standarderror
0.372394183	-0.259578383	-0.665571528	-0.101309776

TEST 4 - NORMALITY TESTS (LOT Pre-Post Test improve scores)			
LOT Pre-Test	LOT Post-Test	LOT Pre-Test	LOT Post-Test
dist1skewness/dist1standarderror	dist2skewness/dist2standarderror	dist1kurtosis/dist1standarderror	dist2kurtosis/dist2standarderror
-0.435813108	-0.298363627	1.653550601	0.149990428

TEST 5 - NORMALITY TESTS (HOT Pre-Post Test improve scores)			
HOT Pre-Test	HOT Post-Test	HOT Pre-Test	HOT Post-Test
dist1skewness/dist1standarderror	dist2skewness/dist2standarderror	dist1kurtosis/dist1standarderror	dist2kurtosis/dist2standarderror
0.353361373	-1.101317615	-0.524929982	2.35600344

Intervention 3:

TEST 1 - NORMALITY TESTS (Gp I vs Gp II combined pre-test scores)			
Gp I	**Gp II**	**Gp I**	**Gp II**
dist1skewness/dist1standarderror	**dist2skewness/dist2standarderror**	**dist1kurtosis/dist1standarderror**	**dist2kurtosis/dist2standarderror**
0.145429743	-0.244795768	0.425697711	-0.053868353

TEST 2 - NORMALITY TESTS (Dev VS Energy improve scores)			
DEV improve	**ENER improve**	**DEV improve**	**ENER improve**
dist1skewness/dist1standarderror	**dist2skewness/dist2standarderror**	**dist1kurtosis/dist1standarderror**	**dist2kurtosis/dist2standarderror**
1.087793283	-0.145047011	2.2671542	-0.434627749

TEST 3 - NORMALITY TESTS (DI vs GD improve scores)			
DI improve	**GD improve**	**DI improve**	**GD improve**
dist1skewness/dist1standarderror	**dist2skewness/dist2standarderror**	**dist1kurtosis/dist1standarderror**	**dist2kurtosis/dist2standarderror**
0.486004552	0.360275865	-0.251888439	0.212706093

TEST 4 - NORMALITY TESTS (LOT Pre-Post Test improve scores)			
LOT Pre-Test	**LOT Post-Test**	**LOT Pre-Test**	**LOT Post-Test**
dist1skewness/dist1standarderror	**dist2skewness/dist2standarderror**	**dist1kurtosis/dist1standarderror**	**dist2kurtosis/dist2standarderror**
0.313333677	-1.571967219	1.319580901	2.627326422

TEST 5 - NORMALITY TESTS (HOT Pre-Post Test improve scores)			
HOT Pre-Test	**HOT Post-Test**	**HOT Pre-Test**	**HOT Post-Test**
dist1skewness/dist1standarderror	**dist2skewness/dist2standarderror**	**dist1kurtosis/dist1standarderror**	**dist2kurtosis/dist2standarderror**
-0.371336251	0.137761978	-0.22192206	-0.321209341

Appendix G: Quantitative Results

Intervention 1:

Test 1 – Comparing ability levels of each group

Gp I vs Gp II combined pre-test means

Between-groups two-sample t-test

	Variable 1	*Variable 2*
Mean	52.94117647	50.0625
Variance	130.4338235	83.2625
Observations	17	16
Pooled Variance	107.6089896	
Hypothesized Mean Difference	0	
df	31	
t Stat	0.796702286	
P(T<=t) one-tail	0.215841801	
t Critical one-tail	2.452824193	
P(T<=t) two-tail	0.431683602	
t Critical two-tail	2.744041919	

Descriptive Statistics

Mean	52.94117647	50.0625
Standard Error	2.76994185	2.281207191
Median	55	47.5
Mode	64	44
Standard Deviation	11.42076283	9.124828766
Sample Variance	130.4338235	83.2625
Kurtosis	-0.137451447	-0.801889827
Skewness	-0.663834676	0.520550075
Range	40	30
Minimum	27	37
Maximum	67	67
Sum	900	801
Count	17	16
	4.5205E-184	4.5205E-184

Test 2 – Influence of prior knowledge

Each group's Development vs Energy improvement scores

Paired within-group t-test

	Variable 1	*Variable 2*
Mean	2.909090909	5.363636364
Variance	23.02272727	24.11363636
Observations	33	33
Pearson Correlation	-0.243917793	
Hypothesized Mean Difference	0	
df	32	
t Stat	-1.841473937	
P(T<=t) one-tail	0.037419184	
t Critical one-tail	2.448677634	
P(T<=t) two-tail	0.074838368	
t Critical two-tail	2.738481482	

Descriptive Statistics

Mean	2.909090909	5.363636364
Standard Error	0.835259482	0.854819427
Median	3	5
Mode	8	5
Standard Deviation	4.79820042	4.910563752
Sample Variance	23.02272727	24.11363636
Kurtosis	-0.432196784	-0.531963438
Skewness	0.012632909	0.331119683
Range	19	20
Minimum	-6	-4
Maximum	13	16
Sum	96	177
Count	33	33
	-5.9385E-241	-5.9385E-241

Test 3 – Hypothesis 1

Total improvement for each Group under DI or GD conditions

Paired within-group t-test

	Variable 1	*Variable 2*
Mean	4.242424242	4.03030303
Variance	25.75189394	24.46780303
Observations	33	33
Pearson Correlation	-0.290372506	
Hypothesized Mean Difference	0	
df	32	
t Stat	0.151377892	
P(T<=t) one-tail	0.440313968	
t Critical one-tail	2.448677634	
P(T<=t) two-tail	0.880627936	
t Critical two-tail	2.738481482	

Descriptive Statistics		
Mean	4.242424242	4.03030303
Standard Error	0.883380112	0.861074083
Median	4	3
Mode	2	3
Standard Deviation	5.074632395	4.946494014
Sample Variance	25.75189394	24.46780303
Kurtosis	-0.242256752	-0.272952866
Skewness	0.289233288	0.05492231
Range	21	19
Minimum	-5	-6
Maximum	16	13
Sum	140	133
Count	33	33
	-1.26646E+42	-1.26646E+42

Test 4 – Hypothesis 2

Means of improvement between Pre- and Post-Test LOT scores

Paired within-group t-test

	Variable 1	*Variable 2*
Mean	28.15151515	36.09090909
Variance	29.00757576	23.71022727
Observations	33	33
Pearson Correlation	0.734668714	
Hypothesized Mean Difference	0	
df	32	
t Stat	-12.11014567	
P(T<=t) one-tail	8.61366E-14	
t Critical one-tail	2.448677634	
P(T<=t) two-tail	1.72273E-13	
t Critical two-tail	2.738481482	

Descriptive Statistics

Mean	28.15151515	36.09090909
Standard Error	0.937559303	0.847638918
Median	29	37
Mode	25	36
Standard Deviation	5.385868153	4.869314867
Sample Variance	29.00757576	23.71022727
Kurtosis	-0.147538218	1.515073751
Skewness	0.023625946	-0.923175942
Range	25	23
Minimum	16	21
Maximum	41	44
Sum	929	1191
Count	33	33
	-1.26646E+42	-1.26646E+42

Test 5 – Hypothesis 3

Means of improvement between Pre- and Post-Test HOT Scores

Paired within-group t-test

	Variable 1	*Variable 2*
Mean	23.39393939	23.72727273
Variance	36.37121212	23.20454545
Observations	33	33
Pearson Correlation	0.45667664	
Hypothesized Mean Difference	0	
df	32	
t Stat	-0.333123095	
P(T<=t) one-tail	0.370607097	
t Critical one-tail	2.448677634	
P(T<=t) two-tail	0.741214194	
t Critical two-tail	2.738481482	

Descriptive Statistics

Mean	23.39393939	23.72727273
Standard Error	1.049837103	0.838551158
Median	23	23
Mode	22	22
Standard Deviation	6.030855007	4.817109658
Sample Variance	36.37121212	23.20454545
Kurtosis	-0.647627669	-0.338901482
Skewness	-0.169631184	0.456887737
Range	23	19
Minimum	11	15
Maximum	34	34
Sum	772	783
Count	33	33
	-1.26646E+42	-1.26646E+42

Intervention 2:

Test to confirm that the students in Intervention 2 were of higher ability than those in Intervention 1

Compare sum of students combined pre-test scores in Intervention 1 with Intervention 2

Between sample t-test

	Variable 1	*Variable 2*
Mean	51.54545455	63.175
Variance	106.3806818	70.25064103
Observations	33	40
Pooled Variance	86.53460307	
Hypothesized Mean Difference	0	
df	71	
t Stat	-5.316102831	
P(T<=t) one-tail	5.84413E-07	
t Critical one-tail	2.380023686	
P(T<=t) two-tail	1.16883E-06	
t Critical two-tail	2.646863444	

Descriptive Statistics

Mean	51.54545455	63.175
Standard Error	1.795454545	1.325241874
Median	53	62.5
Mode	64	60
Standard Deviation	10.31410112	8.381565547
Sample Variance	106.3806818	70.25064103
Kurtosis	-0.664514477	0.691076793
Skewness	-0.169596835	0.070244052
Range	40	38
Minimum	27	43
Maximum	67	81
Sum	1701	2527
Count	33	40
	-4.8248E-220	-4.8248E-220

Test 1 – Comparing ability levels of each group

Gp I vs Gp II combined pre-test means

Between-groups two-sample t-test

	Variable 1	*Variable 2*
Mean	64.08695652	61.94117647
Variance	73.08300395	67.93382353
Observations	23	17
Pooled Variance	70.91492798	
Hypothesized Mean Difference	0	
df	38	
t Stat	0.796663194	
P(T<=t) one-tail	0.215298061	
t Critical one-tail	2.428567631	
P(T<=t) two-tail	0.430596122	
t Critical two-tail	2.711557602	

Descriptive Statistics

Mean	64.08695652	61.94117647
Standard Error	1.782560493	1.99902658
Median	63	62
Mode	60	58
Standard Deviation	8.548859804	8.242197737
Sample Variance	73.08300395	67.93382353
Kurtosis	0.231310666	2.048826001
Skewness	0.170882604	-0.12311282
Range	35	38
Minimum	45	43
Maximum	80	81
Sum	1474	1053
Count	23	17
	4.5205E-184	4.5205E-184

Test 2 – influence of prior knowledge

Each group's Development vs Energy improvement scores

Paired within-group t-test

	Variable 1	*Variable 2*
Mean	7.925	9.7
Variance	22.63525641	18.11282051
Observations	40	40
Pearson Correlation	0.32684184	
Hypothesized Mean Difference	0	
df	39	
t Stat	-2.140256649	
P(T<=t) one-tail	0.019322519	
t Critical one-tail	2.42584141	
P(T<=t) two-tail	0.038645039	
t Critical two-tail	2.707913184	

Descriptive Statistics

Mean	7.925	9.7
Standard Error	0.752250896	0.672919395
Median	8	10
Mode	8	11
Standard Deviation	4.757652405	4.255915943
Sample Variance	22.63525641	18.11282051
Kurtosis	-0.349576373	-0.632295715
Skewness	-0.141946692	0.351127068
Range	21	16
Minimum	-3	3
Maximum	18	19
Sum	317	388
Count	40	40
	-5.9385E-241	-5.9385E-241

Test 3 – Hypothesis 1

Total improvement for each Group under DI or GD conditions

Paired within-group t-test		
	Variable 1	*Variable 2*
Mean	8.675	8.95
Variance	18.48141026	23.84358974
Observations	40	40
Pearson Correlation	0.277700702	
Hypothesized Mean Difference	0	
df	39	
t Stat	-0.314075415	
P(T<=t) one-tail	0.37756885	
t Critical one-tail	2.42584141	
P(T<=t) two-tail	0.7551377	
t Critical two-tail	2.707913184	

Descriptive Statistics		
Mean	8.675	8.95
Standard Error	0.679731753	0.772068484
Median	8.5	9.5
Mode	6	6
Standard Deviation	4.299001077	4.882989837
Sample Variance	18.48141026	23.84358974
Kurtosis	-0.452410102	-0.078218085
Skewness	0.253128151	-0.200412289
Range	17	22
Minimum	1	-3
Maximum	18	19
Sum	347	358
Count	40	40
	-1.26646E+42	-1.26646E+42

Test 4 – Hypothesis 2

Means of improvement between Pre- and Post-Test LOT scores

Paired within-group t-test

	Variable 1	*Variable 2*
Mean	35.075	44.2
Variance	17.55833333	15.13846154
Observations	40	40
Pearson Correlation	0.591973808	
Hypothesized Mean Difference	0	
df	39	
t Stat	-15.76899372	
P(T<=t) one-tail	8.1313E-19	
t Critical one-tail	2.42584141	
P(T<=t) two-tail	1.62626E-18	
t Critical two-tail	2.707913184	

Descriptive Statistics

Mean	35.075	44.2
Standard Error	0.662539307	0.615192278
Median	35	44.5
Mode	36	45
Standard Deviation	4.190266499	3.890817593
Sample Variance	17.55833333	15.13846154
Kurtosis	1.095542269	0.092272953
Skewness	-0.288743315	-0.183550999
Range	20	17
Minimum	24	36
Maximum	44	53
Sum	1403	1768
Count	40	40
	-1.26646E+42	-1.26646E+42

Test 5 – Hypothesis 3

Means of improvement between Pre- and Post-Test HOT scores

Paired within-group t-test

	Variable 1	*Variable 2*
Mean	28.1	36.6
Variance	25.06666667	16.65641026
Observations	40	40
Pearson Correlation	0.372192435	
Hypothesized Mean Difference	0	
df	39	
t Stat	-10.44049177	
P(T<=t) one-tail	3.7216E-13	
t Critical one-tail	2.42584141	
P(T<=t) two-tail	7.44321E-13	
t Critical two-tail	2.707913184	

Descriptive Statistics		
Mean	28.1	36.6
Standard Error	0.791622806	0.645298579
Median	28	37
Mode	30	33
Standard Deviation	5.006662228	4.081226563
Sample Variance	25.06666667	16.65641026
Kurtosis	-0.415546545	1.520325673
Skewness	0.279728922	-0.710678692
Range	20	20
Minimum	18	24
Maximum	38	44
Sum	1124	1464
Count	40	40
	-1.26646E+42	-1.26646E+42

Intervention 3:

Test to confirm that the students in Intervention 3 were of middle ability compared with the high-ability students in Intervention 2

Compare the sum of students combined pre-test scores in Int 2 vs 3

Between sample t-test

	Variable 1	*Variable 2*
Mean	63.175	47.14814815
Variance	70.25064103	69.9002849
Observations	40	27
Pooled Variance	70.11049858	
Hypothesized Mean Difference	0	
df	65	
t Stat	7.684775259	
P(T<=t) one-tail	5.29934E-11	
t Critical one-tail	2.385096816	
P(T<=t) two-tail	1.05987E-10	
t Critical two-tail	2.653604469	

Descriptive Statistics

Mean	63.175	47.14814815
Standard Error	1.325241874	1.60900573
Median	62.5	49
Mode	60	49
Standard Deviation	8.381565547	8.360639025
Sample Variance	70.25064103	69.9002849
Kurtosis	0.691076793	0.344360279
Skewness	0.070244052	-0.426452368
Range	38	38
Minimum	43	26
Maximum	81	64
Sum	2527	1273
Count	40	27
	-4.8248E-220	-4.8248E-220

Test to confirm that the students in Intervention 1 were of same ability compared with those in Intervention 3

Compare the sum of students combined pre-test scores in Int 1 vs 3

Between sample t-test

	Variable 1	*Variable 2*
Mean	51.54545455	47.14814815
Variance	106.3806818	69.9002849
Observations	33	27
Pooled Variance	90.02740044	
Hypothesized Mean Difference	0	
df	58	
t Stat	1.785922462	
P(T<=t) one-tail	0.03966981	
t Critical one-tail	2.392377475	
P(T<=t) two-tail	0.079339619	
t Critical two-tail	2.663286954	

Descriptive Statistics

Mean	51.54545455	47.14814815
Standard Error	1.795454545	1.60900573
Median	53	49
Mode	64	49
Standard Deviation	10.31410112	8.360639025
Sample Variance	106.3806818	69.9002849
Kurtosis	-0.664514477	0.344360279
Skewness	-0.169596835	-0.426452368
Range	40	38
Minimum	27	26
Maximum	67	64
Sum	1701	1273
Count	33	27
	-4.8248E-220	-4.8248E-220

Test 1 – Comparing ability levels of each group

Gp I vs Gp II combined pre-test means

Between-groups two-sample t-test

	Variable 1	*Variable 2*
Mean	48	46.23076923
Variance	52.76923077	92.52564103
Observations	14	13
Pooled Variance	71.85230769	
Hypothesized Mean Difference	0	
df	25	
t Stat	0.541898483	
P(T<=t) one-tail	0.296343009	
t Critical one-tail	2.485107175	
P(T<=t) two-tail	0.592686018	
t Critical two-tail	2.787435814	

Descriptive Statistics

Mean	48	46.23076923
Standard Error	1.941450687	2.667837514
Median	49	47
Mode	49	53
Standard Deviation	7.264243303	9.619024952
Sample Variance	52.76923077	92.52564103
Kurtosis	0.826471113	-0.143712013
Skewness	0.282344674	-0.653075333
Range	28	33
Minimum	36	26
Maximum	64	59
Sum	672	601
Count	14	13
	-5.9385E-241	-5.9385E-241

Test 2 – influence of prior knowledge

Each group's Development vs Energy improvement scores

Paired within-group t-test		
	Variable 1	*Variable 2*
Mean	10.61764706	12.5
Variance	25.0311943	28.07575758
Observations	34	34
Pearson Correlation	0.450948078	
Hypothesized Mean Difference	0	
df	33	
t Stat	-2.031257573	
P(T<=t) one-tail	0.02517355	
t Critical one-tail	2.4447942	
P(T<=t) two-tail	0.050347101	
t Critical two-tail	2.733276642	

	Descriptive Statistics	
Mean	10.61764706	12.5
Standard Error	0.858027737	0.908712042
Median	10.5	12
Mode	11	10
Standard Deviation	5.003118457	5.298656205
Sample Variance	25.0311943	28.07575758
Kurtosis	1.945281187	-0.394951469
Skewness	0.933356809	-0.131805965
Range	24	22
Minimum	2	0
Maximum	26	22
Sum	361	425
Count	34	34
	-5.9385E-241	-5.9385E-241

Test 3 – Hypothesis 1

Total improvement for each Group under DI or GD conditions

Paired within-group t-test

	Variable 1	*Variable 2*
Mean	11.58823529	11.52941176
Variance	21.64349376	33.28698752
Observations	34	34
Pearson Correlation	0.411412535	
Hypothesized Mean Difference	0	
df	33	
t Stat	0.059848936	
P(T<=t) one-tail	0.476318465	
t Critical one-tail	2.4447942	
P(T<=t) two-tail	0.95263693	
t Critical two-tail	2.733276642	

Descriptive Statistics		
Mean	11.58823529	11.52941176
Standard Error	0.797855467	0.989458966
Median	11	10
Mode	11	10
Standard Deviation	4.652256846	5.769487631
Sample Variance	21.64349376	33.28698752
Kurtosis	-0.200970568	0.21046395
Skewness	0.387761388	0.356478185
Range	19	26
Minimum	3	0
Maximum	22	26
Sum	394	392
Count	34	34
	-1.26646E+42	-1.26646E+42

Test 4 – Hypothesis 2

Means of improvement between Pre- and Post-Test LOT scores

Paired within-group t-test

	Variable 1	*Variable 2*
Mean	29.35294118	41.61764706
Variance	25.56862745	21.6372549
Observations	34	34
Pearson Correlation	0.253272942	
Hypothesized Mean Difference	0	
df	33	
t Stat	-12.03820911	
P(T<=t) one-tail	6.41152E-14	
t Critical one-tail	2.4447942	
P(T<=t) two-tail	1.2823E-13	
t Critical two-tail	2.733276642	

Descriptive Statistics

Mean	29.35294118	41.61764706
Standard Error	0.867189976	0.797740465
Median	29.5	42.5
Mode	31	44
Standard Deviation	5.056543034	4.651586278
Sample Variance	25.56862745	21.6372549
Kurtosis	1.14432733	2.095924602
Skewness	0.271719824	-1.254021861
Range	25	22
Minimum	18	27
Maximum	43	49
Sum	998	1415
Count	34	34
	-1.26646E+42	-1.26646E+42

Test 5 – Hypothesis 3

Means of improvement between Pre- and Post-Test HOT scores

Paired within-group t-test

	Variable 1	*Variable 2*
Mean	19.05882353	29.91176471
Variance	27.26916221	8.567736185
Observations	34	34
Pearson Correlation	0.468224083	
Hypothesized Mean Difference	0	
df	33	
t Stat	-13.640609	
P(T<=t) one-tail	2.03062E-15	
t Critical one-tail	2.4447942	
P(T<=t) two-tail	4.06123E-15	
t Critical two-tail	2.733276642	

Descriptive Statistics

Mean	19.05882353	29.91176471
Standard Error	0.895563612	0.501988287
Median	19	30
Mode	19	29
Standard Deviation	5.221988339	2.927069556
Sample Variance	27.26916221	8.567736185
Kurtosis	-0.198745322	-0.161243327
Skewness	-0.332555234	0.069154899
Range	21	12
Minimum	8	24
Maximum	29	36
Sum	648	1017
Count	34	34
	-1.26646E+42	-1.26646E+42

Test to examine whether there was any significant difference in the improvement of HOTS between Intervention 1 and 3

Compare the sum of students combined HOTS improvement in Intervention 1 vs 3

Between sample t-test

	Variable 1	*Variable 2*
Mean	0.333333333	10.85294118
Variance	33.04166667	21.52317291
Observations	33	34
Pooled Variance	27.19381599	
Hypothesized Mean Difference	0	
df	65	
t Stat	-8.255122078	
P(T<=t) one-tail	5.14224E-12	
t Critical one-tail	2.385096816	
P(T<=t) two-tail	1.02845E-11	
t Critical two-tail	2.653604469	

Descriptive Statistics

Mean	0.333333333	10.85294118
Standard Error	1.000631114	0.795634651
Median	0	11
Mode	-3	7
Standard Deviation	5.74818812	4.639307373
Sample Variance	33.04166667	21.52317291
Kurtosis	-0.440689618	0.522761465
Skewness	0.313595772	0.598606188
Range	23	21
Minimum	-11	2
Maximum	12	23
Sum	11	369
Count	33	34
	-4.8248E-220	-4.8248E-220

Appendix H: Ethics Approval

Office of the Deputy Vice-Chancellor
(Research)

Research Office
Research Hub, Building C5C East
Macquarie University
NSW 2109 Australia
T: +61 (2) 9850 4459
http://www.research.mq.edu.au/
ABN 90 952 801 237

MACQUARIE University
SYDNEY·AUSTRALIA

9 October 2017

Mr John Kinniburgh
Department of Education
Faculty of Human Sciences and Humanities
Macquarie University
NSW 2077

Dear Mr Kinniburgh,

Reference No: 5201001530

Title: *How do different GIS-related pedagogies enhance higher order thinking and conceptual understanding in secondary school Geography?*

This letter is to confirm that the ethics application cited above met the requirements set out in the *National Statement on Ethical Conduct in Human Research* (2007 – Updated May 2015) (the *National Statement*).

The application received approval from the Macquarie University Human Research Ethics Committee on 17 February 2011.

The above project was conducted by Mr John Kinniburgh under the supervision of Dr Grant Kleeman.

Please do not hesitate to contact me if you have any questions.

Yours sincerely

Dr Karolyn White
Director, Research Ethics & Integrity
Chair, Macquarie University Human Research Ethics Committee

This HREC is constituted and operates in accordance with the National Health and Medical Research Council's (NHMRC) *National Statement on Ethical Conduct in Human Research* (2007) and the *CPMP/ICH Note for Guidance on Good Clinical Practice.*