Can Learning Geographic Information Systems be Improved for Interdisciplinary Researchers?

A Comparative Study of Formal/Informal Learning Approaches and the Relevance of Context

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I, Patrick Ronald Rickles confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Abstract

In an increasingly complex world, interdisciplinary approaches in research are becoming necessary to address challenges faced by modern society. Universities are progressively acknowledging this and new collaborative opportunities are being recognised between disciplines. When undertaking Interdisciplinary Research (IDR), words may not have the same meaning in other disciplines and, if a commonly understood methodology of work is not established, there may be confusion or serious misunderstandings. IDR comes with a unique set of challenges and suggested solutions; however, that does not mean they may be implemented so easily.

The field of Geography lends itself well to IDR, as it has been described as an integrator for other disciplines. Therefore, a Geographic Information System (GIS) as a spatial analysis tool from Geography may be aligned for IDR. However, GIS in IDR adds another dimension of complexity, as those who need to learn it may have difficulties doing so. GIS educators and educational materials try to help quickly skill people up in new areas; however, how are these efforts perceived by interdisciplinary researchers and can they be improved upon?

This research begins by highlighting that challenges in IDR, which relate to issues including conflicts or gaps of knowledge between disciplines, time constraints, differing agendas or personality conflicts. These may be addressed through training and building relationships with other learners. To understand the concepts of learning, various educational theories and learning approaches were reviewed to ascertain ways of framing and presenting educational resources. From older theories, such as behaviourism, to more contemporary ones, such as context based learning, educators can improve their practices and materials to hopefully better suit the learner by understanding who the learner is, what they wish to learn and how they would go about learning it (in this case, GIS). Determining which GIS concepts are of interest to interdisciplinary learners required the use of a standard structure to investigate them. International GIS curricula were evaluated, which included the NCGIA Core Curriculum and its successor the Geographic Information Science and Technology Body of Knowledge. The Knowledge Areas and descriptions of topics from the latter were selected to frame concepts in a flexible way for activity contexts for this research.

With challenges in IDR and suggested solutions highlighted as well as categories of GIS concepts to explore, an analysis of existing IDR studies that used GIS is carried out to determine current approaches to using GIS and where they succeed and fail. This involved gathering information from relevant research articles by mining Google Scholar and a year-long survey, administered online, that asked interdisciplinary researchers that learned GIS how they went about doing so. A more in-depth exploration was then carried out through a series of interviews with interdisciplinary researchers to understand why they learned GIS in the way they did and the contexts they applied it in. Additionally, a review of learning diaries kept by GIS learners to provide insight into their own learning process was carried out. Overview findings from Google Scholar and the survey show difficulties come from gaps in knowledge around GIS and that training opportunities are looked upon favourably. The interviews and learning diaries highlighted that people believed face-to-face training was a time efficient manner of learning, in comparison to informal methods (e.g. internet searches, watching videos, etc.). Altogether, the results showed interest in web GIS platforms and using a GIS to create, analyse and visualise contextually relevant data, which related back to core concepts from the Geographic Information Science & Technology Body of Knowledge.

Based on these findings, an online resource was developed to teach GIS concepts identified as important to interdisciplinary researchers, through contextually relevant lessons, minimising on extra-disciplinary information and simplifying GIS terms. This was used to explore contextual relevance of lessons and formal and informal learning approaches with interdisciplinary researchers. It was found that while context may play a role, motivation for learning GIS may be a more important factor. Additionally, training resources must be mindful about language used to improve understanding. This work provides guidance on what to change for GIS learning materials and teaching approaches to better accommodate IDR and learners outside the discipline.

Keywords: Interdisciplinary Research, GIS Education, Context Based Learning, Online Tutorials

Impact Statement

This research's purpose was to investigate how to improve the learning experience of Geographic Information Systems (GIS) for interdisciplinary researchers. Interest in this topic is based on the researcher's experiences of working with others on interdisciplinary projects and their difficulties in learning and applying GIS. Learners should be better supported, allowing them to incorporate GIS into their work before they become frustrated and disregard GIS.

Interdisciplinary challenges and suggested solutions, educational approaches and GIS curricula were explored to frame continued investigative work. Alongside standard inquiry methods, novel approaches were employed using custom-built tools. Surveys, interviews and learning diaries were coordinated by the researcher to explore interdisciplinary GIS education, alongside data mining via screen scraping processes using dedicated code. The framework for those learning GIS in interdisciplinary research (IDR) is a novel output that can help guide GIS educators in structuring learning resources. Teaching materials were tailored for interdisciplinary researchers learning GIS and the learning resource developed is available for continued use. This was built using the WordPress platform and the main plugin for it was bespoke. The developed tools, methodologies and outputs shed light on the under-researched area of interdisciplinary GIS education.

The innovative approaches and outputs have been well received by peers and colleagues, acknowledging their importance and impact. The researcher secured over £10,000 of funding, and involved colleagues from across UCL to investigate interdisciplinary GIS applications across Science, Technology, Engineering, and Mathematics subjects. To share research findings, the researcher presented at 14 international conferences, and organised sessions for the Royal Geographical Society's annual conference consecutively for 5 years. Results were published in peer-reviewed journals (Rickles & Ellul, 2014a; Rickles & Ellul, 2014b; Rickles, Ellul & Haklay, 2017) and the researcher has coordinated 2 symposia with the Journal of Geography in Higher Education, to publicise the relevance of this work (Rickles & Ellul, 2014b; Rickles & Ellul, 2017). Based on expertise in interdisciplinary GIS education, the researcher has been an invited speaker and participant for 4 international workshops and has contributed to 2 GIS bodies of knowledge (Rickles, Ellul & Haklay, 2017; Shook et al., 2019). The developed resource, GL4U, has also won 2 professional awards for innovation in GIS education. These demonstrate the success of this research and the impact it has had in reinvigorating discussions and renewing interest in GIS education.

As IDR using GIS grows - inside and outside academia – so does the number of users who need support. Building on the outputs of this research could be beneficial for assisting new users and helping to develop the discipline of GIS. Commercially, fostering this community of practice could embed GIS in organisations and the methodologies of this research could be employed by internal or external educators. Organisations focused on GIS education, such as Esri Inc., have sections of their company devoted to developing learning materials and delivering training. The outputs of this research could be used to improve their practice globally and has already inspired their own online, open education resource (learn.arcgis.com).

Acknowledgements

I initially found writing an acknowledgment to thank all the people who helped me along my journey completing this work surprisingly difficult to do. I wanted to make sure I did not forget to thank everyone; however, it is inevitable that I will miss thanking some people, which I can assure is purely accidental.

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Some have said that a PhD can be a lonely journey, but even with its highs and lows, I never felt that, as all of my friends, colleagues and family have been there for me. Thank you from the bottom of my heart for always believing in me.

Table of Contents

Table of Figures

Table of Tables

Acronyms

- AAG - American Association of Geographers
- AGOL - ArcGIS Online
- BoK - Body of Knowledge
- CBL - Context Based Learning
- CGIS - Canada Geographic Information System
- Challenging RISK - Challenging Resilience by Integrating Societal and Technical Knowledge
- CI - Cyber Infrastructure
- CK - Content Knowledge
- CMS - Content Management System
- CRS - Coordinate Reference System
- CSD - Collaborative Spatial Delphi
- DBMS - Database Management System
- DPU - Development Planning Unit
- ExCiteS - Extreme Citizen Science
- GIS - Geographic Information System
- GIS&T - Geographic Information Science & Technology
- GISc - Geographic Information Science
- GIScientists - Geographic Information Scientists
- GL4U - GIS Lessons for You
- GPS - Global Positioning System
- ICES - Institution of Civil Engineering Surveyors
- IDE - Integrated Development Environment
- IDR - Interdisciplinary Research
- IOE - Institute of Education
- IQR - Inter-Quartile Range
- JCM - José Carlos Mariátegui
- KAs - Knowledge Areas
- KML - Keyhole Markup Language
- LAC - Learning Activity Context
- LEC - Learning Environment Context
- NCGIA - National Center for Geographic Information and Analysis
- OECD – Organisation for Economic Cooperation and Development

- OGC - Open Geospatial Consortium
- PBL - Problem Based Learning
- PCK - Pedagogical Content Knowledge
- PK - Pedagogical Knolwedge
- PNG - Portable Network Graphics
- RTPI - Royal Town and Planning Institute
- SDI - Spatial Data Infrastructure
- SELCS - School of European Languages, Culture and Society
- SHP - Shapefile
- SQL - Structured Query Language
- STEM – Science Technology Engineering Mathematics
- TCK - Technological Content Knowledge
- TIN - Triangulated Irregular Network
- TK - Technological Knowledge
- TPACK - Technological Pedagogical Content Knowledge
- TPK - Technological Pedagogical Knowledge
- UCGIS - University Consortium for Geographic Information Science
- VARK - Visual, Aural, Read/Write, Kinaesthetic
- VLE - Virtual Learning Environment

Definitions

- Activity Theory: learning theory that focuses learning on the motive of the activity, the specific goal to be achieved from the action and the conditions around operation (Podolskiy, 2012, p. 83)
- Andragogy: the art and science of helping adults learn (Fidishun, 2012, p. 143)
- Behaviourism: learning theory based on the study of behaviour, its modification, and its observable antecedents and consequences. (Phillips, 2012, p. 438)
- Community of Practice: learning is achieved through groups of people who wish to learn something collaborating both in the real and virtual world. (Ataizi, 2012a, p. 654)
- Constructivism: learning is collaborative, learner centred and requires activity from the learner. (Gogus, 2012, p. 783)
- Context Based Learning: a pedagogical methodology that, centres on the belief that both the social context of the learning environment and the real, concrete context of knowing are pivotal to the acquisition and processing of knowledge (Rose, 2012, p. 799)
- Formal Learning: learning that is in an intentional, organised structure arranged by institutes (Colardyn & Bjornavold, 2004).
- Geographic Information Science: the scientific study of fundamental issues around the creation, handling, storage and use of geographic information (Longley et al, 2010).
- Geographic Information System: a system able to capture, store, analyse, manage and present data that are linked to geographical locations (Bhat, Shah & Ahmad, 2011)
- Humanism: learning theory that is learner centred and takes into consideration not only intellect, but also a person's interests, goals and enthusiasm. (Sharp, 2012, p. 1469)
- Informal Learning: learning that does not have a specified curriculum, is not taught by an educator and is not formally assessed or certified. (Hager, 2012, p. 1557). It is learning that is spontaneous and experientially driven (Colardyn & Bjornavold, 2004).
- Interdisciplinary: research in which the contributions of several disciplines are integrated and, more importantly, necessary to address a problem or issue (Stember, 1991).

- Multidisciplinary: research approaches that involve several disciplines that each provide a different perspective on a problem or issue (Stember, 1991).
- Non-Formal Learning: learning that may or may not be institutionally led and is more loosely organised (Colardyn & Bjornavold, 2004).
- Problem Based Learning: an instructional method that promotes learners' abilities and skills in applying knowledge, solving problems, practicing higher order thinking, and self-directing their own learning. (Jonassen & Hung, 2012, p. 2687)
- Reflection: gaining better understanding of an issue, event, or encounter by asking questions around "why" and "how" we go about doing or thinking about something. (Al-Mahmood, 2012, p. 2811)
- Self-Directed Learning: learning is goal-oriented and motivated and directed by the learner. (Bouchard, 2012, p. 2997)
- Situated Cognition: the study of human learning that takes place when someone is doing something in both the real and virtual world, and therefore learning occurs in a situated activity that has social, cultural, and physical contexts. (Ataizi, 2012b, p. 3082)
- Social Constructivism: constructivism with emphasis on the importance of culture and social context for cognitive development. (Gogus, 2012, p. 784)
- Transdisciplinary: research approaches that involves the unity of intellectual frameworks beyond the disciplinary perspectives (Stember, 1991) and may lead to the establishment of a new discipline altogether.

Chapter 1 - Introduction

Academic research projects allow a unique opportunity to analyse and solve the major problems of society. These problems, regardless of their perceived size, are complex and multifaceted and, as such, "...resist understanding or resolution when approached from single disciplines." (Golding, 2009, p. 2); to truly understand them, multiple disciplines would need to be incorporated. Disciplines place boundaries around bodies of knowledge, though, which facilitates efficient teaching, provides guidance on research norms, and allows students to establish a solid background in one field of study so they may effectively contribute to interdisciplinary research (National Academy of Sciences et al., 2004, p. 62; Lyall & Meagher, 2012, p. 616). The relationship between disciplines and interdisciplinarity should not be viewed as one-sided, but rather, considered as symbiotic. Both can benefit from one another, as interdisciplinary collaborations can lead to new research methodologies that can add to disciplinary analyses, and disciplines themselves bring established analytic methods that can be considered the tools interdisciplinary research (IDR) needs. IDR can also facilitate strong, cross-departmental, collaborative relationships with peer faculty members, which can persist and lead those involved to new projects, new ways of thinking, and perhaps the establishment of new fields of study.

When considering these issues it is first important to establish the definition of "interdisciplinary" in comparison to similar concepts: "multidisciplinary" and "transdisciplinary". Figure 1.1 is a visualisation that illustrates the differences between these.

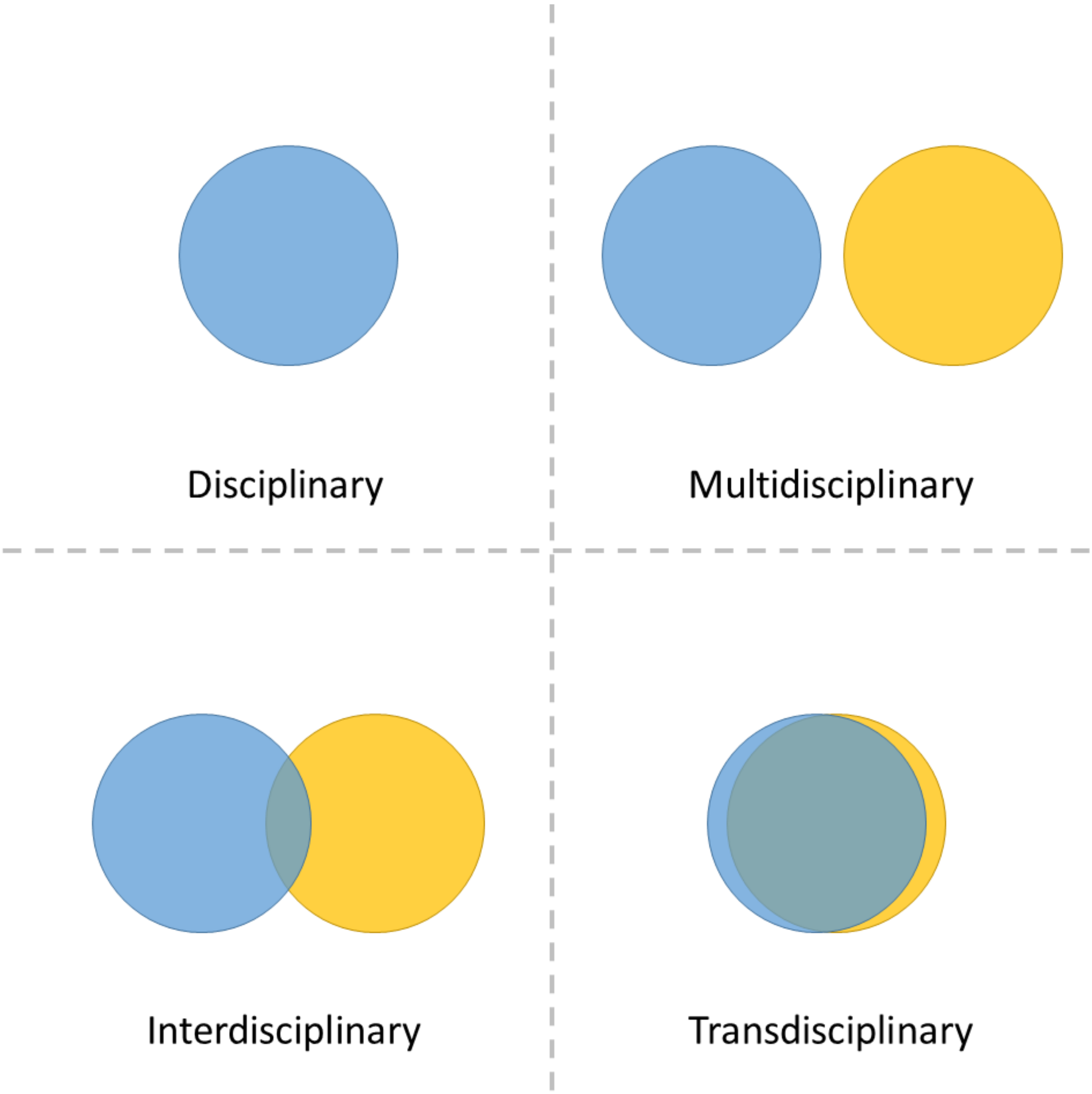


Figure 1.1 Illustrative differences between Disciplinary, Multidisciplinary, Interdisciplinary and Transdisciplinary

Multidisciplinary approaches are ones that involve several disciplines that each provide a different perspective on a problem or issue (Stember, 1991). Researchers on multidisciplinary projects will work in a “parallel play” mode, completing work in their disciplinary work streams and exchanging outputs as and when needed, only fostering a loose continued connection between researchers (Aboelela et al., 2007). The term interdisciplinary research is sometimes used for multidisciplinary research; in a broad sense, “… interdisciplinarity literally means ‘between disciplines’, suggesting the basic elements of at least two collaborators, at least two disciplines, and a commitment to work together in some fashion in some domain.” (Stember, 1991, p. 4). To clarify, though, interdisciplinary research may be considered that in which the contributions of several disciplines are integrated and, more importantly, necessary to address a problem or issue (Stember, 1991). The data and analytical methods may also be more mixed, requiring researchers from one discipline to learn, at least a bit, about methodologies from the other disciplines (Aboelela et al., 2007). Transdisciplinary work, in comparison, involves the unity of intellectual frameworks beyond the disciplinary perspectives (Stember, 1991) and may lead to the establishment of a new discipline altogether. Problems are stated in a way that include completely new language, new analytical methods are established that will be a synthesis of work from the disciplines and outputs from the project are completely new (Aboelela et al., 2007). As such, though, there may be difficulties finding relevant publications, due to the innovativeness of what is attempting to be established and differences from the home, or “pure”, disciplines involved.

The transdisciplinary field that could emerge from what may have initially been interdisciplinary research could potentially receive some level of criticism from the disciplines that it may have emerged from. The ideas of maintaining “discipline purity” over a hybrid discipline, however, seem a bit at odds with the fact that disciplines themselves are relatively new and did not exist until the eighteenth or nineteenth century (Szostak, 2007, p. 89). Prior to the establishment of disciplines, many of the great works of humanity were interdisciplinary, or possibly “pre-disciplinary”. Interdisciplinarity came into conception in its more modern form by Hjort (1921) in “The Unity of Science”, where he discusses the ideas of philosophical systems and unifying scientific hypotheses. The goals he set out, though, were quite lofty and somewhat difficult to actualise; instead, today’s interdisciplinary goals focus on the creation of different complementary and overlapping perspectives.

In comparison, “pure” disciplinary studies, though important in their own right, have been criticised for their narrow approaches to problem solving. Some have stated that single disciplinary research does not keep up with rapid developments of modern society and may even be said to impede the pace of scientific discovery (Interdisciplinary Research - Overview (The NIH Common Fund), n.d.; Stehr & Weingart, 2000). Counter to this, IDR in particular is increasingly being recognised for its ability to provide holistic, sustainable solutions to real world problems. The United Nations, for example, have set forth 17 sustainable development goals that will require interdisciplinary collaboration, which are as follows:

- Goal 1: No poverty
- Goal 2: Zero hunger
- Goal 3: Good health and well-being
- Goal 4: Quality education

- Goal 5: Gender equality
- Goal 6: Clean water and sanitation
- Goal 7: Affordable and clean energy
- Goal 8: Decent work and economic growth
- Goal 9: Industry, innovation and infrastructure
- Goal 10: Reduced inequalities
- Goal 11: Sustainable cities and communities
- Goal 12: Responsible consumption and production
- Goal 13: Climate action
- Goal 14: Life below water
- Goal 15: Life on land
- Goal 16: Peace, justice and strong institutions
- Goal 17: Partnerships for the Goals

These goals seek to free humanity from poverty, secure a healthy planet for generations and to build peaceful, inclusive societies as a foundation for ensuring lives of dignity for all (The Sustainable Development Goals Report, 2017). Various organisations are promoting and funding such initiatives and believe that many future discoveries will come from IDR (National Academy of Sciences, National Academy of Engineering & Institute of Medicine, 2004, p. 85, 153, 159; Lyall & Meagher, 2012, p. 609; Meagher & Lyall, 2005, p. 1; National Science Foundation, n.d.).

This growth in opportunity has been recognised by scholars and has brought together many who may not have seen the commonality their disciplines have. Those in Urban Studies may be interested in the buildings and networks of a place to understand how people move through it, and Anthropologists focusing on people and their motivations may be able to find out a bit more about what those people are doing within that space. By combining these two disciplines, scientists from one discipline may be able to cross-validate (or invalidate) the other's findings and help improve the knowledge of both. However, unless given the opportunity, these people may never have worked together, only looking at one side of the problem, but never understanding the other.

In order for researchers from different disciplines to work towards the desired outputs of the project, they will need to fill in the gaps of knowledge between their disciplines, which is a common challenge in IDR (discussed in 2.1 The Current State of Interdisciplinary Research). This learning process will take time that is often not accounted for in the original project plans due to a lack of understanding the effort involved to establish the connection between disciplines, or simply disregarding it. The amount that needs to be learned could be said to be dependent upon the requirements of the individual and the project, as some may need to delve deeper into other disciplines to perform the analyses necessary for their own work or, as stated by Robertson, Martin and Singer (2003, p. 2), explore “trading zones”. It is important to establish these as well as a commonly understood methodology of work, to avoid confusion or serious misunderstandings later.

1.1 Geographic Information Systems in IDR

The field of Geography foundationally explores the location of people and objects, which is critically important to our lives and informed decision making. Given that questions associated with location can cut across disciplines, Geography lends itself well to IDR and has been described as an integrator for other disciplines (Baerwald, 2010). Spatial analysis techniques from Geography can be used to investigate interdisciplinary questions by integrating information from diverse sources into one framework – the map. A Geographic Information System (GIS), which is a fundamental tool for analysing spatial data (Chen, 1998), is used by Geography and may therefore also be well aligned for use in IDR.

Indeed, referencing the real-world applications of IDR and the United Nation’s Sustainable Development Goals, it has been recognised that geospatial information may have a role in addressing these. For example, in order to achieve Goal 1: End poverty, GIS can be used to understand where disadvantaged areas and populations are by mapping socio-economic data; land ownership; the location of natural resources; workforce productivity; and access to education, healthcare and food security (The Role of Geospatial Information in the Sustainable Development Goals, 2015). For Goal 3: Good health and well-being, GIS may be used to record the location of crimes, disease outbreaks, social data on health and where services and people are, or are not, being connected (The Role of Geospatial Information in the Sustainable Development Goals, 2015). Furthermore, with respect to Goal 13: Climate action, GIS could provide analyses around the profile of land, hazards, exposure and vulnerability (The Role of Geospatial Information in the Sustainable Development Goals, 2015). GIS is applicable beyond the aforementioned goals, as it is not only a vital integrator of many disparate datasets, but also a medium to visually communicate information, providing a platform for discussion.

Recognising the value GIS has to offer IDR, some prominent studies have already successfully applied it to enrich their analyses. In this report examples of such studies can be found in 4.1 Google Scholar Analysis, and are summarised as follows:

- Allan, Erikson and Fay (1997) analysed river ecosystems, using GIS to understand land use and topographic effects with regard to biotic integrity.

- Pereira and Itami (1991) did multivariate regression modelling of habitat suitability for the Mt. Graham red squirrel with GIS.
- Sheehan et al. (2003) investigated the use of corn grain harvest residue for the production of fuel, mapping out ethanol production plants in Iowa.
- Malczewski (2006) presented a literature review on development and trends associated with the integration of GIS and multi-criteria decision analyses.
- Nuckols, Ward and Jarup (2004) used GIS to understand and assess exposure to contaminants in environmental epidemiology studies.
- Corwin and Wagenet (1996) used GIS to manipulate, review and display spatial data on nonpoint source pollutants.
- Boulos (2004) proposed GIS as a platform to educate and empower professionals and the public on community health and healthcare practices.
- Arnold Jr. and Gibbons (1996) incorporated GIS as part of their study on polluted runoff from impervious surfaces in urbanised areas to present impacts on water resources.
- Basili et al. (2008) used mapping and GPS data on seismic activity, recorded over 20 years, to understand the spatial relationships between adjacent tectonic faults, both at the surface and at depth.
- Walsham and Sahay (1999) shared research on the use of GIS between 1993 and 1995 to aid district-level administration, which draws from actor-network theory.

Altogether, based on its use real-world and research applications, it can be seen that those from various disciplines wishing to look into locational issues have embraced GIS. This may be largely from the fact that it offers tremendous potential as an analytical system in a large research and information management environment (Chen, 1998, p. 261) and can be used to:

1. Allow disparate data sets to be brought together to create a complete picture of a situation
2. Illustrate relationships, connections and patterns that are not necessarily obvious in any one data set
3. Facilitate the sharing, coordination and communication of key concepts within and between organisations. (Esri, 2003)

With the advent of open data and open source software, GIS can now be thought of as a very accessible and useful tool for researchers. However, learning how to use a GIS can be a daunting task. As stated by Traynor and Williams (1995, p. 288):

“Off-the-shelf geographic information system software is hard to use unless you have sufficient knowledge of geography, cartography, and database management systems; are computer literate; and invest sufficient time to become accustomed to an interface that reflects the system architecture.”

This highlights the need for new users to properly understand GIS concepts, which are within the discipline of Geographic Information Science (GISc) – the scientific study of fundamental issues around the creation, handling, storage and use of geographic information (Longley et al, 2010). The learning of tools like GIS should be underpinned by sound educational theory and an epistemological framework (Bednarz, 2000; Kerski, 2003; Hualong, 2009; Liu et al, 2012). It is suggested by this research, initially in 2.1 The Current State of Interdisciplinary Research, to provide training on disciplinary tools and methodologies to help create common understanding for those coming from outside of the discipline who may not be familiar with such concepts.

In IDR, though, time constraints are a noted issue (2.1 The Current State of Interdisciplinary Research) so those who wish to use GIS will not have copious amounts of time to learn it. They will need to learn the key aspects that will be vital to their work, learn them quickly and apply them correctly. One way of doing so may be through providing learners with educational resources that use principles familiar to the student, present concepts in a structured way, ensure materials facilitate engagement through different methods, take into account the potentially varied technical background of students and allow them to be assessed in as equitable manner as possible (Ellul, 2012, p. 441). Indeed, covering irrelevant topics and “...simply moving through a GIS & T [Geographic Information Science & Technology] course from topic to topic using lectures, demonstrations and labs, does not necessarily move all the way around the learning cycle, unless the activities are carefully interlocked and together offer exposure to concrete experience, reflective observation, abstract conceptualization and active experimentation.” (Foote, 2012, p. 87)

In particular, it can be said that adult interdisciplinary researchers when learning GIS will do so in a problem centred fashion and are interested in immediate application of knowledge (Merriam, 2004). The process of adult learning itself is a study, known as andragogy (Knowles, 1980, p. 43), as adults learn new concepts differently in comparison to the ways children do, which is more the focus of pedagogy (Merriam, 2001, p. 6). To present types of learning, the Organisation for Economic Cooperation and Development (OECD) provides definitions for Formal, Non-Formal, and Informal learning. Formal learning may be defined as an intentional, organised structure arranged by institutes. Non-Formal learning may or may not be institutionally led and is more loosely organised. Informal learning may be considered to be spontaneous, experiential learning (Colardyn & Bjornavold, 2004). More structured formal or non-formal courses or sources can neatly pull together relevant information, which may be of great value to the learners and expedite the learning process, if materials are presented in an effective manner. Comparatively, informal learning may allow learners to “cherry-pick” information from various resources to answer the questions and self-teach necessary skills. These approaches as well as others have been mapped by Loo (2014), which is presented in Figure 2.1 and will be explored in 2.2 Educational Approaches.

Therefore, with respect to adult interdisciplinary researchers, would a formal/non-formal approach or an informal one be more conducive for learning GIS? This research seeks to investigate this by looking at the nexus between the topics of GIS, IDR and Education, as represented in Figure 1.2. Initial work on understanding IDR projects and how researchers learn to use tools and methodologies from other disciplines would be necessary to inform and direct the research of this report. A series of preliminary investigations in interdisciplinary settings were conducted to gain insight into any issues that may have arisen, how they might be solved and which GIS concepts were of relevance. The findings of these case studies, which personally involved the researcher, were formed by work with the Adaptable Suburbs project, the Extreme Citizen Science (ExCiteS) research group and the Development Planning Unit (DPU) and will be discussed in greater detail in Chapter 3.

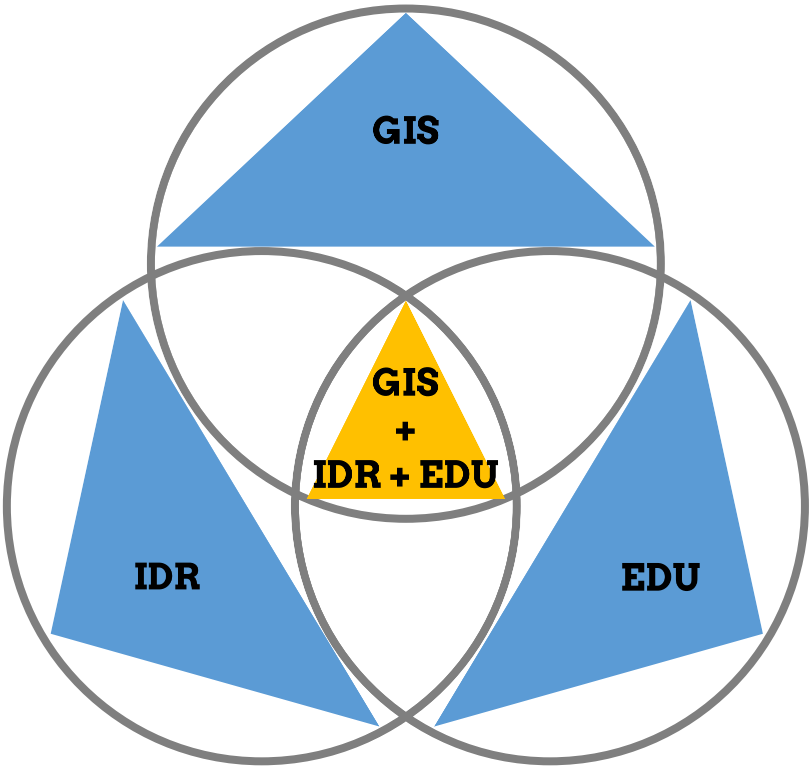


Figure 1.2 *Diagram representation of this research's areas of interest and their nexus*

1.2 Summary

In this introduction, IDR has been defined and differentiated from other types of research. Though it provides unique opportunities, IDR is not without its challenges and suggested solutions. GIS can be a useful tool in IDR, but it may be difficult to learn or even, more fundamentally, to articulate how to use it to identify what to learn. Different learning approaches exist that may be better aligned with IDR; however, this will need to be explored. Having worked with the researchers from the groups in the preliminary case studies that have been introduced, as well as others, it was observed that their understanding of GIS and the way they went about learning and applying GIS may be improved upon.

Tying all of these concepts together, the main research question to be explored by this body of work is how can learning GIS be improved for interdisciplinary researchers? This may be addressed by answering the following sub-questions:

1. What challenges do people face in interdisciplinary research and how is it suggested that they solve those issues?
2. Which GIS concepts are relevant to people in IDR?

3. Which educational approaches may be relevant to learning GIS and how do they compare to one another?
4. What are some of the learning approaches people involved in IDR have used to learn GIS?
5. Can a contextually relevant mixed formal (institutionally led)/non-formal (loosely organised) learning resource improve uptake and application of GIS in IDR?

Figure 1.3 shows which chapters of this report answer these questions; relevant details and research that helped to form them will be discussed in Chapter 2 and Chapter 3. The questions were derived from reflection on the elements of GIS, educational approaches and IDR, as illustrated in Figure 1.2. In order to understand how people learn to use GIS, concepts associated with learning itself must first be explored. IDR is different to disciplinary research, so it is necessary to understand complexities that may be unique to it that researchers may encounter. Researchers may have particular reasons for employing GIS, so it is important to know if they are commonly trying to use it for a specific purpose. As GIS has previously been utilised in IDR, researchers will have also had to learn GIS; by learning how they did so, lessons may be learnt about what techniques do and do not work. By understanding that, a new method or resource may be suggested that could help these researchers learn GIS in a better way.

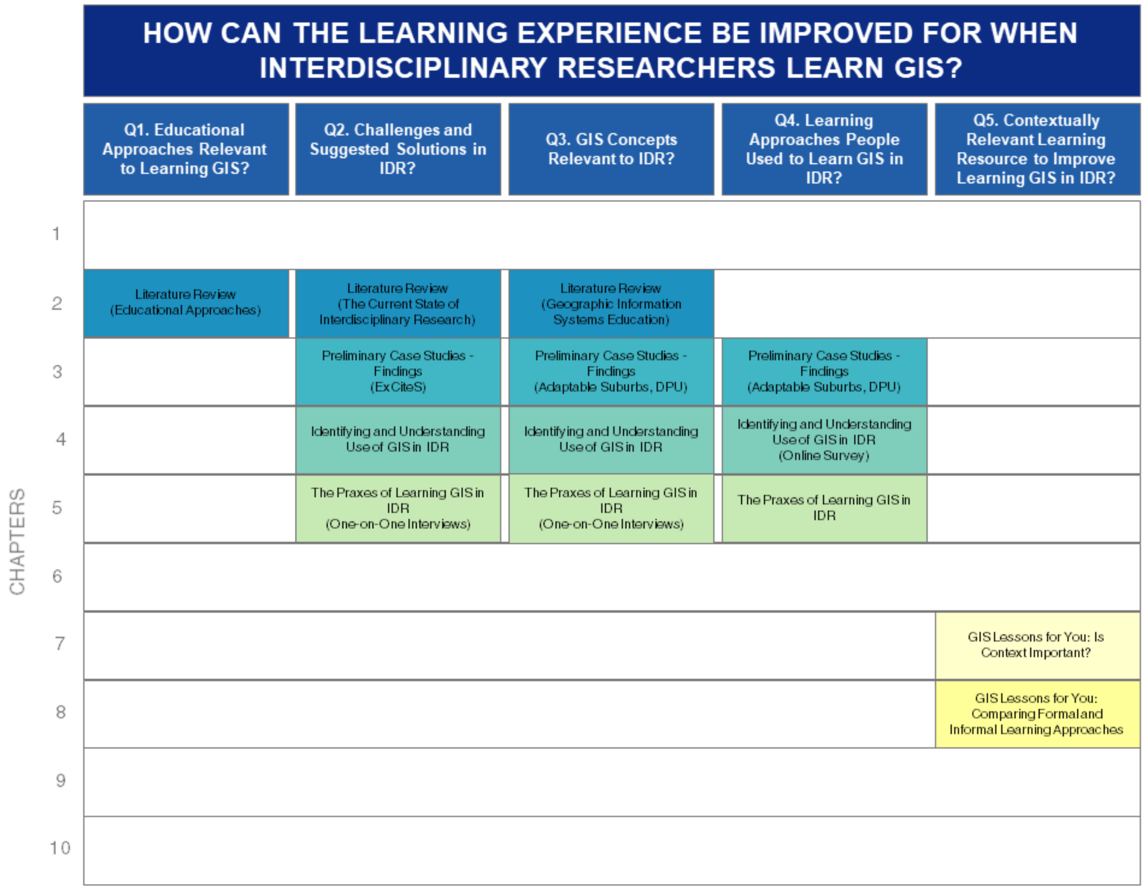


Figure 1.3 Research Questions and the Chapters that Address Them

1.3 Overview of this Thesis

This work therefore begins by seeking to understand issues around IDR (2.1 The Current State of Interdisciplinary Research), different approaches to learning (2.2 Educational Approaches) and GIS learning programmes that outline important concepts to learn (2.4 Geographic Information Systems Education). The current way that GIS is learned by those in IDR (Formal/Non-Formal or Informal) is then explored through a review of published studies (4.1 Google Scholar Analysis), a comprehensive survey (4.2 Online Survey), interviews (5.1 One-on-One Interviews) and learning diaries kept by those learning GIS (5.2 Learning Diaries). Based on these findings, various frameworks are reviewed and an appropriate one is selected and modified for guidelines on helping interdisciplinary researchers learn GIS (Chapter 6). This is then used to underpin the creation of a learning resource to review the relevance of the learning activity context (Chapter 7) and compare formal/non-formal and informal learning environment contexts (Chapter 8). The overall research findings are then discussed (Chapter 9) and a summary of the report with further suggestions is presented (Chapter 10).

The results from this research may be used by GIScientists to improve educational practices to benefit not only interdisciplinary researchers, but GIS learners overall. These key findings, summarised in Chapter 10, are as follows:

- The most common challenges in IDR are time constraints and the knowledge gap. The most common suggested solutions are building relationships and providing training.
- Context Based Learning (CBL) does not necessarily provide any advantages for GIS learners in IDR, although it is important to use contexts that the learner will understand to improve the learning experience.
- Interdisciplinary researchers are most interested in learning how to create, analyse and visualise information in a GIS. They often use ArcGIS, QGIS and web GIS platforms for their work.
- The modified Technological Pedagogical Content Knowledge (TPACK) framework for learning GIS in IDR can be used by both research teams and commercial and open GIS software vendors to provide appropriate learning materials to meet learners' needs.
- It is possible to learn how to use a GIS successfully without any formal training. However, learners prefer a formal tutorial as this gives them more confidence in and continued motivation for using GIS.
- GIS Lessons for You (GL4U) not only demonstrated a flexible approach to GIS learning, but also how a standard website framework such as WordPress – usually used for blogging – could be adapted into a tool for creating flexible, reusable learning material.

Chapter 2 - Literature Review

Three main areas of literature will be reviewed to inform the research of this report, which are Interdisciplinary Research, Education Theory, and the structure of existing formal Geographic Information Science (GISc) curricula. The first will provide information on the background and current work of interdisciplinary research (IDR), to assess common issues encountered. With understanding of this, further research may be able to circumnavigate these and incorporate suggested solutions to aid researchers on these projects, which may be complementary to the goal of learning Geographic Information Systems (GIS). From there, theories on education can suggest various approaches for conveying information, and therefore a conducive approach may be selected for learning GIS. Finally, GISc programmes are looked into in order to understand how they have refined themselves and evolved to ensure that important concepts are taught to those wishing to enter into the field.

Altogether, these strands of research will help frame how adults learn and how to successfully teach GISc concepts to use GIS in IDR, and handle common IDR issues before they arise, utilising relevant suggested approaches. Indeed, this research is itself interdisciplinary, combining interdisciplinary literature, teaching and learning theories and GISc, which will provide insight into important, yet under researched cross-sections between these disciplines that may be beneficial to future research initiatives.

2.1 The Current State of Interdisciplinary Research

IDR has been defined in Chapter 1 and, given its importance, there is an extensive range of literature that looks specifically at this topic. Broadly speaking, this can be divided into two, very much overlapping, themes – literature that outlines challenges faced by IDR and literature that suggests solutions. For both challenges and solutions, there are examples employed by the preliminary case studies, which will be discussed in Chapter 3.

These themes were derived initially from "Facilitating Interdisciplinary Research" (National Academy of Sciences, National Academy of Engineering & Institute of Medicine, 2004). While reviewing this book, IDR issues and suggested solutions to them that were mentioned were noted; these were grouped based on commonalities that began to emerge. For example, it was said that "… progress toward interdisciplinary expertise may be slowed by a relative shortage of interdisciplinary postdoctoral fellowships." (National Academy of Sciences, National Academy of Engineering & Institute of Medicine, 2004, p. 67). It was also later said, in a reflection on the results of a survey conducted with interdisciplinary researchers that they felt that their work was disadvantaged relative to those focusing on single disciplines for a few reasons. Those stated were about "…relatively short submission deadlines, pressure to understate costs for IDR proposals, the page limit on proposals, the difficulty of teaming administratively with investigators in different institutions, and a lack of a well-defined review path for IDR proposals." (National Academy of Sciences, National Academy of Engineering & Institute of Medicine, 2004, p. 116). Together, these denote an issue, amongst potentially others, around opportunities for interdisciplinary researchers, which became one of the IDR challenge themes and the other challenges as well as the suggested solutions were created in a similar fashion.

Articles were then reviewed to verify the IDR challenges and suggested solutions or used to derive new ones that may not have been suggested in the book. These came from a variety of disciplines, which includes Education, Geography, Environmental Science, Urban Planning, Medicine, Social Science, Management, Interdisciplinary Studies and Political Science. This provides multiple perspectives on interdisciplinarity that have helped to validate the identified IDR challenges and suggested solutions.

Table 2.1 presents the identified challenges in IDR and Table 2.2 shows suggested solutions and describes them in greater detail; both of these have been ordered by most to least commonly encountered in the literature sources.[1] These have all also been classified as to which level of operation they may be exhibited or implemented – the project or institutional level. At the project level, researchers may see more localised issues arise as well as have more efficacy with addressing them. At the institutional level, there is likely little a researcher may be able to do in the immediate term and so they will simply have to adjust to the way their organisation may operate.

These themes will be explored with the preliminary case studies in Chapter 3 to explain the outcomes from these initial investigations and will become a central tenant of the work detailed in this report.

[1] The work described in Table 2.1 and Table 2.2 have been published in Rickles and Ellul (2014a).

Table 2.1 Common Challenges in Interdisciplinary Research

Common Challenges in IDR	Description	References	Level of Relevance
Difficulties Related to Collaborating with Other Disciplines	Team members may not understand another researcher's home discipline or take for granted the implicit knowledge of their own (and how difficult it may have been to master). This could be considered the knowledge gap between the disciplines.	Barisonzi & Thorn, 2003; Bradbeer, 1999; Braddock et al., 1994; Brewer, 1999; Franks et al., 2007; Fry, 2001; Hall & Weaver, 2001; Knights & Willmott, 1997; Lyall & Meagher, 2012; Mansilla & Duraisingh, 2007; National Academy of Sciences et al., 2004; Newell, 1992; Siedlok & Hibbert, 2009; Weinberg & Harding, 2004; Woods, 2006	Project
Personality Conflicts	To handle vulnerabilities, people may establish a "ring-fence" for certain methodologies to be handled by their discipline, or simply focus on their own disciplinary outputs and disregard others'. This may also be due to personality conflicts.	Braddock et al., 1994; Brewer, 1999; Franks et al., 2007; Hall & Weaver, 2001; Morse et al., 2007; National Academy of Sciences et al., 2004; Nash, 2008; Satin, 1994; Siedlok & Hibbert, 2009	Project
Time Constraints	Many issues arise: the amount of time it can take to establish close working relationships, time spent on activities outside of the home department, time spent meeting disciplinary/department obligations as well as fulfilling interdisciplinary outputs, and the extra time it can take to learn about new methods, languages, and cultures.	Barisonzi & Thorn, 2003; Golding, 2009; Lyall et al., 2011; Morse et al., 2007; National Academy of Sciences et al., 2004; Nash, 2008; Panaritis, 1995; Satin, 1994; Weinberg & Harding, 2004	Project
Intransigence from Current Institutional Structure	Difficulties related to limited resources, the current academic reward system, different institutional cultures, program evaluation, different departmental policies and procedures, lengthy project start up times, or decentralised budget strategies.	Braddock et al., 1994; Brewer, 1999; Golding, 2009; Mansilla & Duraisingh, 2007; Morse et al., 2007; National Academy of Sciences et al., 2004; Satin, 1994; Siedlok & Hibbert, 2009	Project
Problems Being at the Interface Between Disciplines	Confusions arising from an overlap in knowledge between the disciplines and differing associated definitions or methodologies. This can be said to be conflicts at the knowledge trading zone between disciplines that can happen between researchers.	Barisonzi and Thorn, 2003; Brewer, 1999; Field and Lee, 1992; Lyall and Meagher, 2012; National Academy of Sciences et al., 2004; Siedlok and Hibbert, 2009	Project

Lack of Opportunities for People	There can be said to be a relative shortage of interdisciplinary postdoctoral fellowships, as well as difficulties with continued professional development, and problems finding and publishing in relevant journals.	Brewer, 1999; Fry, 2001; Lyall et al., 2011; Lyall & Meagher, 2012; Morse et al., 2007; National Academy of Sciences et al., 2004	Institutional
Licencing and Ownership Ambiguities	Ownership can be particularly tricky when it comes to allocation of intellectual-property rights, confidentiality, and liability; especially for multi-department/multi-university collaborations. There may be difficulties agreeing which journals to publish in as one may not be regarded with the same level of importance to others on the project from outside disciplines.	Lyall & Meagher, 2012; National Academy of Sciences et al., 2004; Weinberg & Harding, 2004	Project/Institutional
Lack of Local Level Management	This can commonly be attributed to difficulties for evaluating IDR project progress, as there seems to be no effective mechanism in place to track or set performance goals. Further to that, personal disciplinary interests/disinterest may introduce bias in the direction of the project.	Lyall et al., 2011; Lyall & Meagher, 2012; National Academy of Sciences et al., 2004	Project

Table 2.2 Suggested Solutions to Challenges in Interdisciplinary Research

Suggested Solutions to Challenges in IDR	Description	References	Level of Relevance
Provide Training on Technical and Supplemental Skills	Education on disciplinary tools and methodologies from the disciplines involved may be necessary for the team, as well as possible general skills, such as communication training for facilitation, stakeholder engagement and mediation.	Barisonzi & Thorn, 2003; Franks et al., 2007; Golding, 2009; Hall & Weaver, 2001; Klein, 2005, 2006; Knights & Willmott, 1997; Lyall et al., 2011; Lyall & Meagher, 2012; Morse et al., 2007; Nash, 2008; Newell, 2001; Panaritis, 1995; Satin, 1994; Spelt et al., 2009; Weinberg & Harding, 2004; Woods, 2006	Project/Institutional
Build Relationships with Members of the Group	Fostering a collaborative environment, increasing leadership and team-forming activities, and networking with researchers in other disciplines.	Golding, 2009; Hall & Weaver, 2001; Lyall et al., 2011; Morse et al., 2007; Nash, 2008; Newell, 1992, 2001; Satin, 1994; Weinberg & Harding, 2004	Project
Include Senior Staff and Interested Parties	Mentorship, establishing an advisory board and regular performance reviews can provide the team with the necessary structure to be successful.	Lyall et al., 2011; Lyall & Meagher, 2012; Nash, 2008; Morse et al., 2007; Panaritis, 1995; Weinberg & Harding, 2004	Project
Incorporate Effective Management Practices to Construct Clear Objectives and Evaluation	By setting project benchmarks and special evaluation measures, such as internal and external visiting committees, those managing can ensure the project aims are being met.	Golding, 2009; Hall & Weaver, 2001; Lyall et al., 2011; Morse et al., 2007; Woods, 2006	Project
Increase Funding Opportunities and Adapt Existing Ones for IDR	Projects may require investment and flexibility in current structures for warm-up activities, seed-corn support, team-building interactions, and community building – including involvement of stakeholders.	Lyall et al., 2011; Morse et al., 2007; Nash, 2008; Satin, 1994	Institutional
Incentivise IDR with Support and Rewards	Ideas such as providing higher pay, publication opportunities and job security to move bright, early-career staff out of too-narrow disciplinary pursuits.	Knights & Willmott, 1997; Lyall et al., 2011; Panaritis, 1995	Institutional

Establish an Institutional Structure that Prioritises IDR	Prioritisation can be accomplished by adapting departmental resources and support for research, experimenting with innovative polices and structures, and revising hiring procedures.	Field & Lee, 1992; Lyall et al., 2011	Institutional
Discourage Disciplinary “Selfishness”	No discipline of anyone involved is any more or less important than any other; researchers should know that their reputations will be positively or negatively affected by the overall success or failure of the project.	Morse et al., 2007	Project

2.2 Educational Approaches

Understanding the learning process itself has led to the development of many different learning theories, a number of which embody relevant aspects to learning GIS. Altogether, the theories reviewed are as follows:

- Behaviourism (18^{th}-19^{th} century): learning theory based on the study of behaviour, its modification, and its observable antecedents and consequences. (Phillips, 2012, p. 438)
- Constructivism (late 1800s / early 1900s): learning is collaborative, learner centred and requires activity from the learner. (Gogus, 2012, p. 783)
- Social Constructivism (early 1900s): constructivism with emphasis on the importance of culture and social context for cognitive development. (Gogus, 2012, p. 784)
- Activity Theory (early 1900s): learning theory that focuses learning on the motive of the activity, the specific goal to be achieved from the action and the conditions around operation (Podolskiy, 2012, p. 83)
- Situated Cognition (late 12^{th} century): the study of human learning that takes place when someone is doing something in both the real and virtual world, and therefore learning occurs in a situated activity that has social, cultural, and physical contexts. (Ataizi, 2012b, p. 3082)
- Community of Practice (1991): learning is achieved through groups of people who wish to learn something collaborating both in the real and virtual world. (Ataizi, 2012a, p. 654)
- Humanism (1951): learning theory that is learner centred and takes into consideration not only intellect, but also a person's interests, goals and enthusiasm. (Sharp, 2012, p. 1469)
- Andragogy (1833): the art and science of helping adults learn (Fidishun, 2012, p. 143)
- Self-Directed Learning (late 12^{th} century): learning is goal-oriented and motivated and directed by the learner. (Bouchard, 2012, p. 2997)
- Informal Learning (late 1800s / early 1900s): learning that does not have a specified curriculum, is not taught by an educator and is not formally assessed or certified. (Hager, 2012, p. 1557)
- Reflection (1933): gaining better understanding of an issue, event, or encounter by asking questions around "why" and "how" we go about doing or thinking about something. (Al-Mahmood, 2012, p. 2811)

- Problem Based Learning (1960s): an instructional method that promotes learners' abilities and skills in applying knowledge, solving problems, practicing higher order thinking, and self-directing their own learning. (Jonassen & Hung, 2012, p. 2687)
- Context Based Learning (1990s): a pedagogical methodology that, centres on the belief that both the social context of the learning environment and the real, concrete context of knowing are pivotal to the acquisition and processing of knowledge (Rose, 2012, p. 799)

2.2.1 General Education Theories

Behaviourism is a theory defined by Watson (1924, p. 11) as one which attempts to predict and control human activity. This is an almost mechanistic view of how people learn – good behaviour is rewarded, while bad behaviour is punished, with the intent to reinforce a particular action.

This view fell out of favour for that of constructivism in the late 1980s/early 1990s (Duit & Treagust, 1997, p. 5), where it was believed that learners construct their own knowledge in realistic situations together with others (Kanselaar, 2002, p. 1). Possible reasons for this transition may be that "First, the curricula designed in the 1960s and early 1970s had been far less successful in terms of improvements in the standards of science education, particularly in learning outcomes, than was expected from the effort invest in them. Second, various disciplines relevant to science education, such as philosophy and science, cognitive psychology and pedagogy, encompassed the notions of 'constructivism'." (Duit & Treagust, 1997, p. 5) Constructivism itself later evolved, as its views have changed from those that "...centered on the personal, subjective nature of knowledge construction to views centered on its social, intersubjective nature...These newer views are generally called social constructivism." (Au, 1998, p. 299) This, therefore, emphasises that people learn through our interactions with the world around us and social artefacts.

Bearing in mind the learning environment that can be created by constructivist approaches, Jonassen and Rohrer-Murphy (1999) suggest activity theory act as a framework for such implementations – particularly for the situation of human-computer interaction. Activity theory may be defined as a "philosophical framework for studying different forms of human praxis as developmental processes, both individual and social levels interlinked at the same time" (Kuutti, 1991, p. 532). Centrally, "Activity theory posits that conscious learning emerges from activity (performance), not as a precursor to it." (Jonassen & Rohrer-Murphy, 1999, p. 62). However, situated cognition, which also recognises the importance of the activity, believes it and the environment are two parts of a mutually constructed whole that together is how people socially construct meanings and appropriate social and cultural norms (Hung & Chen, 2001). Through the richness of situations and context of actions, dialectical “struggles” in cognition, whether with other individuals, artefacts, ideas, tools and problems can be said to be where learning truly occurs (Hung, 2002). Taking the individual experience and understanding that these interactions may take place with multiple individuals, it can be recognised that collective learning may take place in a shared domain of human endeavour, leading to the theory of communities of practice (Wenger, 2011). The focus of activity theory, situated cognition and community of practice is that learning in this way is a social act which forms identity and is ultimately demand driven (Brown & Duguid, 2000).

Another theory, proposed in the mid-20th century as a direct response to behaviourism that also moves away from the activity and the context of the environment, is the humanistic approach. Humanism focuses, instead, on the student and their feelings, attitudes, perceptions, and ideas; the emphasis is not on what the educator wants them to achieve, but rather, understanding the student, their intended goals and helping them be successful in achieving them. This approach was largely pioneered by American psychologist, Carl Rogers, and was initially applied to therapy (client-centred therapy) and later applied to education (student-centred education) due to their similar aims to create meaning (Rogers, 1951, p. 11-12). It has been suggested in therapy to achieve a client-centred approach so that there may be “...the creation of an interpersonal situation in which material may come into the client’s awareness, and a meaningful demonstration of the counselor’s acceptance of the client as a person who is competent to direct himself.” (Rogers, 1951, p. 24) This concept may be transposed and applied to education, with the client being the student and the counsellor being the teacher, and focusing on the aim to create a safe environment and let the student know they are accepted. Indeed, in this approach, the individual’s feelings, attitudes, perceptions and ideas are taken into account as being part of the learning process. (Goodman, 1984, p. 12) When established, it may be possible to reach people so that they may reflect on their own experiences to understand them. In order for it to be effective, the counsellor (or yet again, the teacher) must be able to put their own experiences aside and perceive and reflect (but not mimic) the attitude of the person they wish to reach – almost to hold a mirror up to them and ask them what they see and to listen to themselves. Cantor (1946, p. 83-84), summarising these ideas and, reflecting on the humanistic approach to education, stresses that:

- The teacher will be concerned primarily with understanding and not judging the individual
- The teacher will keep at the center of the teaching process the importance of the student's problems and feelings, not his own
- Most important of all, the teacher will realize that constructive effort must come from the positive or active forces within the student

Rogers suggests that "The educational situation which most effectively promotes significant learning is one in which (1) threat to the self of the learner is reduced to a minimum and (2) differentiated perception of the field of experience is facilitated." (Rogers, 1951, p. 391) This corresponds very much to Cantor's first point, in which there is a need to create a safe environment in education. To address Cantor's second point, Rogers postulates that "We cannot teach another person directly; we can only facilitate his learning." (Rogers, 1951, p. 389) Rogers further implies that "A person learns significantly only those things which he perceives as being involved in the maintenance of, or enhancement of, the structure of self." (Rogers, 1951, p. 389), which relates to Cantor's final point. As Rogers phrases it, for the educator to truly engage the student, "He accepts himself as being a member of a learning group, rather than an authority." (Rogers, 1951, p. 427)

2.2.2 Formal, Non-Formal and Informal Learning

Through the application of the approach of Humanism, a number of challenges can arise, with regard to these points. Though students may have specific motivations to learn a given topic, current institutional structures are set up in a way that may be perceived as rigid or disconnected (Freeland, 2001). This may present educators with difficulties with respect to covering what the student may wish to learn as well as adhering to the curriculum that has been set by the department. To aid in fostering a mutually beneficial learning circumstance, teachers should be given the time to learn and to listen to their students and to develop their own techniques for building on what they have learned by listening (Carpenter & Fennema, 1992). This can be at odds, though, with the traditional learning environment, as materials are typically prepared in advance to follow the sequence of the course (Cutts et al, 2004). These materials, if used to prompt and promote in-lecture dialogue between students and educators, could gather information that lecturers and tutors may use to refine their teaching materials to best meet the needs of the students (Cutts et al, 2004).

Bespoke materials that address learners' needs may play an important role in adult education, the study of which is known as andragogy. Adult learners, as defined by Wynne (2006), are people who have:

- Accumulated life experiences and established knowledge
- Maturity, intrinsic goal/relevancy motivations and require active involvement
- Individuality, autonomy and self-direction
- Practical and problem-solving skills
- Logistical considerations such as family care, careers, social commitments, time, money, schedules or transportation
- Concerns about knowledge gaps and inadequacy

This may be used to clearly differentiate the motives of adult learners, in comparison to children, in that learning is problem-centred with learners having interest in immediate application of knowledge (Merriam, 2004). Furthermore, adults, in comparison to children, can be said to have accumulated a reservoir of life experiences that can act as rich resources for learning, that they have an independent self-concept and may thusly direct their own learning. Self-directed learning, which is inherently student-centred (with the self as the student and therefore linked to Humanism), occurs as part of adults' everyday lives and is systematic yet does not depend on an instructor or a classroom (Tough, 1971). This also fits the definition of informal learning, which is not typically classroom-based or highly structured, and control of learning rests primarily in the hands of the learner (Marsick & Watkins, 1990). Equally, this may be linked back to the OECD's definition of informal learning, which is said to be experiential learning and not (formally) organised (Colardyn & Bjornavold, 2004).

As informal learning is based on experiences, the learners' ability to reflect on those experiences may provide further understanding of how knowledge is formed. The roots of reflection as a way of learning may be said to go back to Socrates, who attempted to discover the nature of goodness by asking questions of others; he also challenged the statements and beliefs of his students, including Plato, whose work developed as a consequence of Socrates' training on how to reflect (Daudelin, 1997, p. 37). Reflection is "… the process of stepping back from an experience to ponder, carefully and persistently, its meaning to the self through the development of inference"; the resulting learning helps us to create "…meaning from past or current events that serves as a guide for future behavior." (Daudelin, 1997, p. 39) These events upon which one may reflect, could be formal or informal learning experiences; linking reflection back to educational approaches, such as situated cognition or community of practice, is wholly appropriate, as both consider learning as a process of reflecting, interpreting and negotiating meaning (Stein, 1998).

Focusing on formal educational settings, it is still largely the decision of the educator to set the assessments, determine the most appropriate educational approach for facilitating knowledge construction, and then compile and deliver the materials in the best way they see fit. It has been noted that “the assumption that the lecture method, and its satellite the tutorial, should be defaults that academics use in discharging their teaching duties needs examining” (Biggs & Tang, 2011, p. 74). With that said, though, traditional lectures are still considered by some to be relatively effective for presenting information, and that students would prefer really good lectures or well-conducted group work (Biggs & Tang, 2011, p. 136); therefore, it is important to try and achieve the best lecture possible to motivate students. Indeed, a truly effective lecture can be considered entertainment in itself, with the lecturer bearing in mind elements such as voice clarity and speed, audio-visual aids, effective use of the audience as a resource, and the ability to entertain (Gelula, 1997, p. 201, 203). Through balancing all of these, the educator can engage students of all learning styles: Visual, Aural, Read/Write, and Kinaesthetic (VARK) (Fleming, 1995, p. 308-309). Though there may be concerns about the validation of the model (Pashler et al, 2008), it can still be acknowledged that there are many personal styles of learning that can be supported in different ways.

Focusing on the content of learning materials, instead of delivery methods, may suggest the possible relevance of further learning approaches. Context Based Learning (CBL) is defined as “… a pedagogical methodology that, in all its disparate forms, centers on the belief that both the social context of the learning environment and the real, concrete context of knowing are pivotal in the acquisition and processing of knowledge.” (Rose, 2012, p. 799). CBL recognises a dual axis of context – one focusing on the social situation of learning and the other on the knowledge interface of the learning activity with actual, empirical reality (Rose, 2012). These could perhaps be better described as the “Learning Environment Context” and the “Learning Activity Context”, respectively, which are part of the proposed framework in 6.4 Proposed Framework – Modified TPACK with Mapped Research Components.

Problem Based Learning (PBL), which is considered a subset of CBL (Overton, Byers & Seery, 2009), “...derives from a theory which suggests that for effective acquisition of knowledge, learners need to be stimulated to restructure information they already know within a realistic context, to gain new knowledge, and to then elaborate on the new information they have learned.” (Kilroy, 2004, p. 411). Authenticity – i.e. relevance to real world problems – of the designed PBL task is necessary to engage the learner and allow them to reflect on the learning process, and this approach builds on the concept of social constructivism, which emphasises that people learn through their interactions with the world around them (Au, 1998, p. 299). It has, however, also been said that PBL resides in the humanist tradition as well, as the student is considered the core of the learning activity (Clayton & Pierpoint, 1996, p. 3).

2.3 Learning in Interdisciplinary Research

Loo (2014) put forward a comprehensive diagram that mapped many of the learning theories that have been reviewed as seen in Figure 2.1. This diagram notes prominent authors in those areas, into three main categories: Psychology, Education and Management. This work served as a basis for which theories to investigate and where this review could be expanded on to create further linkages to other theories (with an update diagram shown in Figure 6.1).

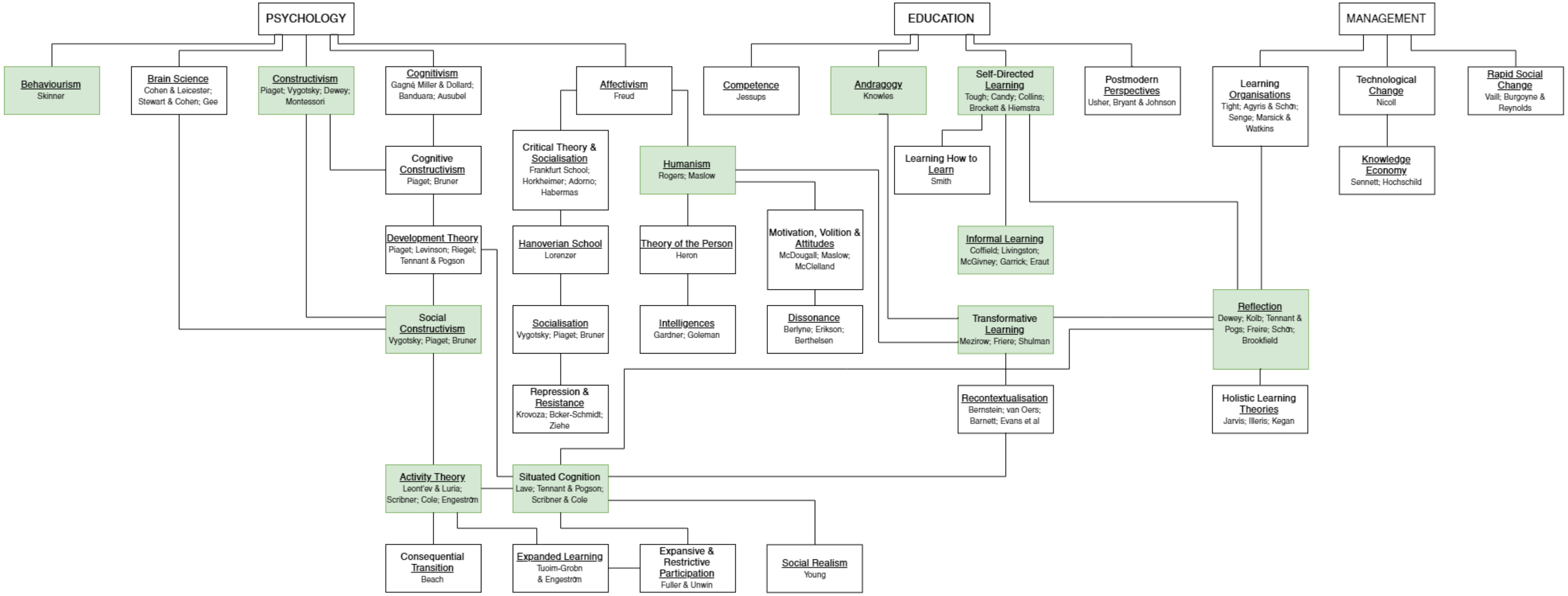


Figure 2.1 Theories of Learning Diagram (Loo, 2014)

To further explain their relevance to IDR, all the learning theories covered have been summarised and tied back to the IDR challenges and suggested solutions in Table 2.3. Each theory is described and explored with respect to IDR challenges and/or their suitability for incorporated suggested solutions. For example, as Behaviourism puts control of the learning situation with the educator and leaves very little to the learner, this may create or exacerbate existing Personality Conflicts, should there be any disagreements; however, this may be conducive in Constructing Clear Objectives. In comparison, Humanism may put the learner at the centre of learning and create a positive learning environment, which may foster opportunities to Build Relationships with other learners or the educator. This, though, may take time to establish and Time Constraints may mean this approach might be less feasible. Ultimately, emerging from this review of how the various approaches handle IDR issues, it can begin to be seen that PBL and CBL may warrant further exploration.

Table 2.3 Educational Theories and IDR Challenges/Solutions they Address

Educational Approach	Description	Suitability to IDR Project (challenges/solutions)
Behaviourism	Desired behaviour encouraged; undesired behaviour discouraged	Authoritarian – may cause “Personality Conflicts” rather than alleviate them. May not adequately address “Problems Being at the Interface Between Disciplines”; power structure may impose definitions. Will have to “Incorporate Effective Management Practices to Construct Clear Objectives and Evaluation”. ”Provide Training on Technical and Supplemental Skills” will largely be conscripted.
Constructivism	Knowledge is built upon existing knowledge/experience	May be challenging for “Difficulties Related to Collaborating with Other Disciplines” as direction for bridging the gap between disciplines may be vague on own. “Provide Training on Technical and Supplemental Skills” will have some input from the learner for direction.
Social Constructivism	Building knowledge upon knowledge is a social process	“Difficulties Related to Collaborating with Other Disciplines” and navigating the “Problems Being at the Interface Between Disciplines” will be well handled by social interaction/negotiations, also addressing any “Personality Conflicts” and at the same time “Provide Training on Technical and Supplemental Skills” in an indirect way and facilitate “Building Relationships with Members of the Group”. Through this, members themselves will “Discourage Disciplinary ’Selfishness’”.
Activity Theory	Learning occurs through activity – not before it	May handle “Time Constraints” by overlapping tasks with learning; may neglect “Providing Training on Technical and Supplemental Skills” as the role of training may be downplayed.
Situated Cognition	Activities and environmental factors are equally important to learning	“Intransigence from Current Institutional Structure” may be a hindrance to this approach; “Include Senior Staff and Interested Parties” may help improve situations and guide work and “Establish an Institutional Structure that Prioritises IDR” may provide channels for improving operations.
Community of Practice	Activities and environmental factors as organised by a community facilitates participation and learning	“Difficulties Related to Collaborating with Other Disciplines”, “Personality Conflicts”, “Problems Being at the Interface Between Disciplines” “Licencing and Ownership Ambiguities” and “Lack of Local Level Management” may all be exacerbated by conflicts arising from the need to work together and establish a community/group. “Intransigence from Institutional Structure” may also create hindrances to optimal operation within community/group. “Time Constraints” may be problematic, considering time needed to establish community/group. “Provide Training on Technical and Supplemental Skills” and “Include Senior Staff and Interested Parties” can help to “Build Relationships with Members of the Group”. “Establishing an Institutional Structure that Prioritises IDR” can help facilitate community/group operations. “Discourage Disciplinary ‘Selfishness’” may help avoid conflicts as well.
Humanistic Approach	Student centred education	Individual needs are taken into account and tailored for, which will involve all members in “Incorporating Effective Management Practices to Construct Clear Objectives and Evaluation”; they will decide on whether there is a need to “Provide Training on Technical and Supplemental Skills” and leave them to “Build Relationships with Members of the

		Group" as they will. Empowering, but will still require some level of monitoring to ensure project outputs are being met and "Time Constraint" issues are not further aggravated.
Andragogy	Adult education	"Time Constraints" may be an issue associated with adult life; "Lack of Opportunities for People" may also be a concern, depending upon where the learner is at in their career. Understanding these issues and ensuring efficiency gains in work through "Providing Training on Technical and Supplemental Skills" and "Incorporating Effective Management Practices to Construct Clear Objectives and Evaluation" may be appealing to researchers.
Self-Directed Learning	Learning controlled by the learner that isn't dependent upon formal learning structures	May help with "Time Constraints", as learners can fit learning around their schedules. Avoids "Building Relationships with Members of the Group" as learning is individually focused and may do nothing to "Discourage Disciplinary 'Selfishness'".
Informal Learning	Experiential, unstructured learning	May help with "Time Constraints" as learners can fit learning around their schedules. Avoids "Building Relationships with Members of the Group" as learning is individually focused and may do nothing to "Discourage Disciplinary 'Selfishness'". "Providing Training on Technical and Supplemental Skills" may be more efficient in uptake of knowledge, but is not utilised.
Reflection	Learning based on review of previous experiences	"Difficulties Related to Collaborating with Other Disciplines" and "Problems Being at the Interface Between Disciplines" may make reflection difficult due to lack of understanding or personal disciplinary bias. "Providing Training on Technical and Supplemental Skills", "Building Relationships with Members of the Group" and "Discouraging Disciplinary 'Selfishness'" may all provide opportunities for reflection and learning.
Problem Based Learning	Knowledge is obtained through a social process of exploring and solving real-world problems that are of interest to the learners	Handles "Difficulties Related to Collaborating with Other Disciplines" and "Problems Being at the Interface Between Disciplines" through real-world (rather than abstract) scenarios that engage the team, bringing them together to hopefully sort any "Personality Conflicts" at the same time by "Building Relationships with Members of the Group" and "Discouraging Disciplinary 'Selfishness'" through focus on solving the problem at hand. This normative process also allows the group to "Incorporate Effective Management Practices to Construct Clear Objectives" agreed by all, addressing any "Lack of Local Level Management" and empowering everyone to be involved.
Context Based Learning	Knowledge is obtained through solving real-world problems that are relevant to the learner	Handles "Difficulties Related to Collaborating with Other Disciplines" and "Problems Being at the Interface Between Disciplines" through real-world (rather than abstract) scenarios that engage learners in a meaningful way, allowing them to bridge gaps and understand different perspectives. "Time Constraints" may be alleviated through "Providing Training on Technical and Supplemental Skills" through relevant problem sets that may facilitate uptake. By collaborating, this could help "Build Relationships with Members of the Group" and help "Discourage Disciplinary 'Selfishness'".

Focusing on PBL and CBL with respect to IDR, PBL will first be investigated, followed by CBL. Savery and Duffy (1995) note that PBL provides a number of advantages, which include the ability to do the following:

- Provide the opportunity to anchor all learning activities to a larger task or problem;
- Support the learning in developing ownership for the overall problem or task;
- Design an authentic task;
- Design the learning environment to support and challenge the learners' thinking;
- Encourage testing ideas against alternative views and alternative context; and
- Provide opportunity for and support reflection on both the content learned and the learning process.

These opportunities are directly relevant to IDR as it has been said that "A problem based learning environment transcends disciplinary boundaries by placing the problem (rather than the discipline) at the centre of the learning environment." (Drennon, 2005, p. 400). Additionally, the concepts and tools used by GIS lend themselves well to the constructivist environment (Keiper, 1999, p. 47) and can be enhanced by the complementary humanist elements of PBL.

However, PBL can be time consuming (Kilroy, 2004) and impose greater demands on time for both teachers and students; in respect to the teachers, there is an increase in responsibility in management of the instructional process and students will have increased workloads and study time, in comparison to more traditional educational approaches (Ribeiro & Mizukami, 2005). CBL not only takes into account the learners' needs, but also the importance of the teachers as well in developing an ideal programme to match those needs, should that be possible for the situation. As Hansman (2001) states:

"… learning in context is paying attention to the interaction and intersection among people, tools, and context within a learning situation. More important, for adult educators who plan and teach, it is understanding how to plan and design programs for adult learners that will profoundly shape learning. And finally, it is incorporating the learners' developmental needs, ideas, and cultural context into the learning experience." (p. 44)

Understanding this, CBL still poses challenges to educators (Avargil et al, 2011) and may require training for them to successfully implement CBL approaches (Parchmann & Luecken, 2010), though hopefully afterwards, they may be able to set up CBL environments more quickly, with experience. Transitively, as PBL is a type of CBL, it may be the case that some of the arguments for **PBL’s** relevance in IDR and/or GIS education, as made earlier, may be applicable to CBL.

However, it may be difficult to discern the distinction between PBL and CBL, as both focus on learning through inquiry into a particular scenario. The differences between these approaches may even be considered overly nuanced. There is a wider body of literature on PBL, in comparison to CBL; therefore, structuring the learning experience using only CBL resources could overlook equally applicable or more appropriate PBL guidance. Initial findings of articles on PBL benefits in previous IDR and GIS studies, which led to interest in CBL, may have also prematurely ended investigations into other learning approaches that have not been reviewed.

Nevertheless, the relevance of CBL to the research outlined in this PhD report may be further strengthened by CBL also being linked to situated cognition, which posits that learning is context bound, tool dependent and socially interactive. Community of practice may also play a role, as it refers to the place in which situated cognition occurs such as with families, in classrooms, a workplace, an online community, a town, or a corporation (Merriam, 2004, p. 211). Communities of practice, as discussed earlier in this section, also links back to reflection, which is associated with self-directed learning and, finally, self-directed learning links to informal learning, which is the method of learning often employed in IDR. Ultimately, referring back to Figure 2.1, what can be seen through the links between discussed theories is that CBL ties together all relevant theories from the Psychology, Education and Management categories – including formal and informal approaches – making it the most promising possible approach for addressing educational needs in IDR.

2.4 Geographic Information Systems Education

In exploring GIS as a tool for IDR, it is important to note the difference in reference between Geographic Information Systems (GIS) and Geographic Information Science (GISc). One of the first GISs developed was the Canada Geographic Information System (CGIS) in 1960 by Roger Tomlinson to digitally capture and store information for the Canada Land Inventory (Coppock & Rhind, 1991, p. 23). The term GIS, itself, is up for much debate, but has been broadly defined as a system able to capture, store, analyse, manage and present data that are linked to geographical locations (Bhat, Shah & Ahmad, 2011); however, CGIS is certainly not the first example of spatial analysis. One of the earliest and most prominent uses of spatial analysis was when John Snow mapped out cholera cases in 1854 in London to determine that residents of the West End were becoming infected by contaminated water from the Broad Street pump (Snow, 1855, p. 23-24). It is the combination of geospatial concepts, which originally derive from geography, and the processing capabilities of computers, which CGIS was a pioneering effort of, that led to the establishment of GISc.

GISc, a term first coined in paper by Michael Goodchild in 1992 (Longley et al, 2010), may be considered the scientific study of fundamental issues arising from the creation, handling, storage and use of geographic information (Longley et al, 2010). GISc emerging from a parent discipline like Geography is unsurprising, as geographic principles often lend themselves to new fields. Geography, itself, has been described as an integrative discipline that "...is placed at the center of this emerging new transdisciplinary synthesis science." (Skole, 2004, p. 740) Skole (2004) continues further by saying:

"Geography's community and pedigree should be expected to change as the discipline embraces these new immigrants from other disciplinary domains who wish to take advantage of the technologies and the interdisciplinary synthesis that geography has to offer." (p. 741-742)

With GISc as a descriptor of the discipline, it can then be said that GIS is a tool utilising the principles of and for, but certainly not limited to, GISc. Indeed, for locational analyses, GIS may be considered to be a fundamental research tool (Chen, 1998, p. 261). With that said, though, GIS is not the best tool for every purpose, as it requires background investment in technology learning, data acquisition and design, which may also be difficult to afford (Cunningham, 2005). Furthermore, GIS is still largely quantitative and technical in orientation, though, which poses difficulties when dealing with social dimensions and qualitative analyses, assessments, and ways of thinking. It is therefore important to understand the purpose of using the GIS and how to use it to successfully apply geospatial concepts to analyses to produce accurate outputs. One may learn this through educational practices that cover relevant topics, but those topics may vary depending upon the educator and learner.

Those who wish to be educated and certified in GISc will in most cases achieve this goal through a structured programme using a standard curriculum in a formal, classroom setting. These are generally taught via undergraduate or Masters level teaching programmes, which can range from one to four years in duration and involve in-depth project work as well as extensive use of GIS tools along with the conceptual learning. The student is thus given extensive time to engage with the complexities of GISc and approaches to learning are a mix of in-class theory (presented in the form of lectures), practical lab-based work and assignments and exams. In these programmes, one of the most prominent textbooks used to teach GISc topics is “Geographical Information Systems and Science” (Longley et al, 2010), which was first published in 2001, has since sold over 100,000 copies internationally and is available in English, Polish, Korean, Chinese, Portuguese and Greek (Longley, personal communication, 01 November, 2016). The contents outlined in this book include 1) Geographic Principles, 2) Geographic Data Handling Techniques, 3) Geographic Analysis and 4) GIS Management, which reflects introductory material relating to topics that may be used as part of the formal learning programmes Geographic Information Scientists receive. Given the widespread use of this text and its popularity for teaching, its topics may be used as a lens for understanding material included in GIS curricula. Bearing this in mind, curricula were reviewed as part of this thesis. This was done in order to select a robust and contemporary one to frame GIS concepts that also embodied the topics from “Geographical Information Systems and Science”. The curricula that were reviewed were as follows:

- NCGIA GIS Core Curriculum (1991)
- The Geographer’s Craft Project (1992)
- European GIS Curriculum (1993)
- Revision of Berry’s Geographic Matrix for GIS (1995)
- Geographic Information Science & Technology (GIS&T) Body of Knowledge (BoK) (2006)[2]
- Japan Standard GIS Core Curriculum (2009)

2.4.1 NCGIA GIS Core Curriculum

The National Center for Geographic Information and Analysis (NCGIA) GIS Core Curriculum was initially submitted to the National Science Foundation for funding to establish a standardised one year course in 1991 that would teach students basic concepts and applications of GIS for a maximum short-term impact. A three course sequence, with 75 one hour units was established and outlined in Figure 2.2. In this, it can be seen that basics similar to Longley et al (2010) are covered, though perhaps by using different terms. For example, concepts in A. Introduction cover basic Geographic Principles, 6. Sampling the world and 7. Data input may be said to relate to Geographic Data Handling Techniques, 15. Spatial analysis to Geographic Analysis and P. Decision-making in a GIS context to GIS Management. Further emerging from this curriculum are

[2] Please note that the GIS&T BoK has been revised and a new version has been published since undertaking this work (‘University Consortium for Geographic Information Science: GIS&T Body of Knowledge’, 2018).

concepts that cover spatial representation, data structuring and issues around planning and implementing a GIS. The comprehensive coverage of these topics seemed to generate interest with the professional GIS world. The final outline was advertised and delivered to a total of 736 interested institutions globally for implementation (428 Educational Institutions, 119 Commercial Organisations, 94 Government Agencies, and 95 Other [individuals, libraries, research institutes, bookstores and publishers]). Editors of the outline were Karen Kemp and Michael Goodchild, both employed by the NCGIA at the time they were working on the curriculum. It was last updated in 2000, to incorporate technological changes (Goodchild & Kemp, 1992), though those who were involved on it have moved on to contribute to other GIS educational efforts.

Introduction to GIS

- A. Introduction
  1. What is GIS?
  2. Maps and map analysis
  3. Introduction to computers
- B. A first view of GIS
  4. Raster GIS
  5. Raster GIS capabilities
- C. Data acquisition
  6. Sampling the world
  7. Data input
  8. Socio-economic data
  9. Environmental data
- D. Spatial databases
  10. Models of reality
  11. Spatial objects and database models
  12. Relationships among spatial objects
- E. Vector view of GIS
  13. Vector GIS
  14. Vector GIS capabilities
- F. Using the GIS
  15. Spatial analysis
  16. Output
  17. Graphic output design issues
  18. Modes of user/GIS interaction
  19. Generating complex products
  20. GIS for archives
- G. Past, present and future
  21. Raster/vector debate
- L. Databases for GIS
  43. Database concepts I
  44. Database concepts II
- M. Error modelling and data uncertainty
  45. Accuracy of spatial databases
  46. Managing error
  47. Fractals
  48. Line generalization
- N. Visualization of spatial data
  49. Visualization of spatial data
  50. Colour theory

Application issues in GIS

- O. GIS application areas
  51. GIS application areas
  52. Resource management applications
  53. Urban planning and management
  54. Cadastral records and LIS
  55. Facilities management
  56. Demographic and network applications
- P. Decision-making in a GIS context
  57. Multiple criteria methods
  58. Location-allocations on networks
  59. Spatial decision support systems
- Q. System planning
  60. System planning overview
  61. Functional requirements analysis
  62. System evaluation

22. Object/layer debate
23. History of GIS
24. GIS marketplace
25. Trends in GIS

Technical issues in GIS

H. Coordinate systems and geocoding
   26. Common coordinate systems
   27. Map projections
   28. Affine and curvilinear transformations
   29. Discrete georeferencing
I. Vector data structures and algorithms
   30. Storage and complex spatial objects
   31. Storage of lines: chain code
   32. Simple algorithms I – line intersection
   33. Simple algorithms II – polygons
   34. Polygon overlay operation
J. Raster data structures and algorithms
   35. Raster storage
   36. Hierarchical data structures
   37. Quadtree algorithms and spatial indexes
K. Data structures and algorithms for surfaces, volumes and time
   38. Digital elevation models
   39. TIN data models
   40. Spatial interpolation I
   41. Spatial Interpolation II
   42. Temporal and 3D databases

   63. Benchmarking
   64. Pilot project
   65. Costs and benefits
R. System implementation
   66. Database creation
   67. Implementation issues
   68. Implementation strategies for large organizations
S. Other issues
   69. GIS standards
   70. Legal issues
   71. Development of a national GIS policy
   72. GIS and global science
   73. GIS and spatial cognition
   74. Knowledge based techniques
   75. The future of GIS

Figure 2.2 The 75 Units of the NCGIA Core Curriculum (Goodchild & Kemp, 1992, p. 311-312)

2.4.2 The Geographer's Craft Project

The Geographer's Craft Project, proposed by Kenneth Foote in 1992 at the University of Texas at Austin, attempts to go beyond the NCGIA Core Curriculum. To do this, the Geographer's Craft used the NCGIA Core Curriculum as a structure for a problem oriented synthesis of techniques that draw upon analyses from cartography, remote sensing and GIS. The materials given to students were tailored to specific problems, to maintain relevance and address real world problems, incorporating hypermedia (audio, video, etc.) as and when appropriate. Figure 2.3 shows the topics that were covered as part of a full year course, split into those covered in Term 1 and Term 2. Though perhaps not apparent in the syllabus topic titles, these classes may still be considered structured by general themes such as Geographic Principles (Term 1: Principles of Cartographic Communication), Geographic Analysis (Term 1: Research Concepts and Exploratory Data Analysis) and those around GIS Management (Term 2: Economic and Legal Relating to GIS and Other Information Technologies). Geographic Data Handling Techniques is not clearly defined by the curriculum topics, though it may be covered within one of the lessons; the focus of the structure of this curriculum is to underpin topics with real world applications. After 1996, there appears to be little to no further work on this project; however, all compiled information is still freely available on the internet for those who wish to use them as an educational resource. Foote further went on to work on the National Science Foundation-funded "Virtual Geography Department" project which ran from 1996 to 2006 and is also now archived. (Foote, 2001; Foote, et al., 2012).

Term 1:	Term 2:
• Introduction	• Introduction to CAD
• Internet Study, Research and Publishing Skills	• CAD Basics and Beyond
• Texas Campaign Strategy	• More CAD Using Public Access Datasets
• Research Concepts and Exploratory Data Analysis	• Three-dimensional Modeling
• Principles of Cartographic Communication	• Rendering and Animation
• Issues in Demographic Mapping	• Depicting Temporal Change Using Animation
• The Resurgence of Cholera in Peru	• Overview of WebGIS
• Project Planning and Data Sources for GIS	• Implementation of WebGIS
• Coordinate Systems	• Coordinate Systems
• Database Concepts and Design	• Questions of Accuracy and Precision and Managing Error
• Introduction to Final Project	• Economic and Legal Relating to GIS and Other Information Technologies
• Overview of WebGIS	• Ethical Issues Relating to GIS and Other Information Technologies
• Principles of Hypertext Design and Publishing	• Trends in GIS Technologies and Presentation of Final Projects

Figure 2.3 *Geographer's Craft Curriculum for Fall 1999 / Spring 2000 (Foote, 2001)*

2.4.3 European GIS Curriculum

The European GIS Curriculum initiative was led by the Technical University of Vienna in 1993 to develop an International Post-Graduate Course on GIS. The research team for this initiative included Andrew Frank, Karen Kemp, Irene Campari, Werner Kuhn and Rebecca Winn. Kemp, as mentioned earlier, was one of the editors for the NCGIA Core Curriculum, so it is likely that that curriculum influenced this proposed course. Kuhn is also known in the area of GIS education, as he has suggested core GIS concepts be taught as part of spatial analyses courses, which include understanding of location, neighbourhood, field, object, network, event, granularity, accuracy, meaning and value (Kuhn, 2012). The final outline for this proposed course based on the team's recommendations is illustrated in Figure 2.4. Themes again emerge around Geographic Principles (1. Spatial concepts and the representation of spatial knowledge), Geographic Data Handling Techniques (5. Data sources for GIS), Geographic Analysis (12. Spatial analysis) and GIS Management (14. Communicating spatial information). Further work on this initiative was not pursued after the publication of the study's findings.

Part one – Spatial information for GIS

0. Introduction to course
1. Spatial concepts and the representation of spatial knowledge
2. Determining and representing location
3. Modelling reality in an information system
4. Spatial concepts as implemented in GIS
5. Data sources for GIS
6. Traditions and use of GIS
7. Needs analysis and feasibility studies for GIS

Assignment of the practical project

Part two – Information systems for GIS

8. Technical aspects of information systems
9. Special information system requirements of GIS
10. Database issues
11. Technical aspects of digital spatial data
12. Spatial analysis
13. Methodologies for system design and selection

Presentation of project proposals

Part three – Practical project

Part four – Using GIS in the organisation

14. Communicating spatial information

15. Economics of geographical information
16. Project management
17. Implementing GIS in an organisation
18. GIS in society
Presentation of projects

Figure 2.4 Outline of Units for the International Post-Graduate Course on GIS (Kemp & Frank, 1996, p. 489)

2.4.4 Revision of Berry's Geographic Matrix for GIS

Berry's Geographic Matrix for GIS is an older concept that was revised in 1995 by Daniel Sui at Texas A & M University (Sui, 1995). The original framework, developed by Brian Berry in 1964, sought to end the continued fragmentation of Geography as a discipline and highlight that perceived dichotomies were artificial and unnecessary. From his analyses he created the subsequent matrix, which can be seen in Figure 2.5.

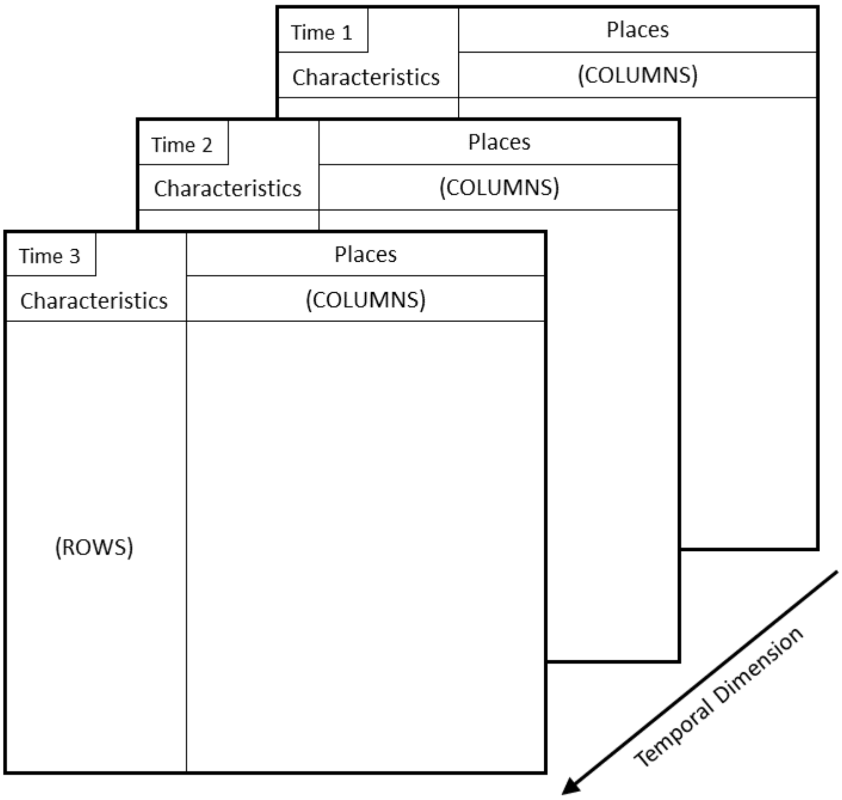


Figure 2.5 *Berry's Geographic Matrix (Sui,* 1995, p. 582)

By taking into account the various sub-disciplines of Geography and how this matrix would be relevant to them, Berry was then able to derive 10 approaches to understanding space. A summary of these approaches can be seen in Figure 2.6.

Summary of Geographic Approaches According to Geographic Matrix	
Matrix Operation	Geographical Meaning
The arrangement of cells within a row or part of a row	The study of spatial distributions and maps
The arrangement of cells within a column or part of a column	The study of localized associations of variables in place, and to locational inventories
Comparison of pairs or of whole series of rows	Study of spatial covariations or spatial associations
Comparisons or pairs or of whole series of columns	Study of areal differentiation
The study of a "box" or submatrix	The study of areal differentiation in its holistic sense; involve two or all of operations 1-4
Comparison of a row or part of a row through time	The study of changing spatial distribution
Comparison of a column or part of a column through time	The study of the changing character of some particular area through a series of stages; the study of subsequent occupance
Comparison of pairs or whole series of rows through time	The study of changing spatial associations
Comparison of pairs of whole series of columns through time	Study of areal differentiation
The study of a "box" or submatrix through time	A process that could involve all of the preceding approaches

Figure 2.6 *Summary of Berry's derived Geographic Approaches (Sui, 1995, p. 582)*

Sui believed that the duality of Berry's work (the abstract matrix and the synthesis of approaches) can also be applied to GIS, when teaching about GIS and teaching with GIS. He then proposes rudimentary GIS concepts (such as raster vs. vector, geoprocessing, etc.) that correspond with the proposed approaches. Sui's concepts as put forward cover aspects of Geographic Analysis of spatial information through understanding of covariations or associations, which may include temporality; though it does not specifically name Geographic Principles, Geographic Data Handling Techniques or GIS Management. Beyond this article, there have been no further developments on the revision of Berry's matrix for GIS; however, Sui has remained active in GIS education.

2.4.5 Geographic Information Science and Technology Body of Knowledge

Geographic Information Science and Technology (GIS&T) Body of Knowledge (BoK) was developed in 2006 by a large number of professionals, coordinated by the Education Committee of the University Consortium for Geographic Information Science (UCGIS) and published by the Association of American Geographers (AAG). The GIS&T BoK hopes to prepare students for success in the variety of professions that rely upon geospatial technologies. The lead editor of the BoK was David DiBiase who established the Online GIS Masters Programme at Penn State University. Also part of the editorial staff was Karen Kemp, who was an editor for the NCGIA Core Curriculum, and Daniel Sui, who proposed the revision to Berry's matrix for GIS, was part of the advisory board, so their previous efforts may have helped to influence and guide the GIST&T BoK.

The BoK begins with ten Knowledge Areas, which are as follows:

- Analytical Methods
- Conceptual Foundations
- Cartography and Visualisation
- Design Aspects
- Data Modeling
- Data Manipulation
- Geocomputation
- Geospatial Data
- GIS&T and Society
- Organizational and Institutional Aspects

These are then further divided into 73 units, 329 topics and over 1600 formal educational objectives to be organised and used as educators see fit to appropriately teach the topics relevant to learners. Given the variety of topics covered, it can be said that many of them, classified by the Knowledge Areas, fall within the main areas of Geographic Principles (Conceptual Foundations), Geographic Data Handling Techniques (Geospatial Data), Geographic Analysis (Analytical Methods) and GIS Management (Organizational and Institutional Aspects).

The GIS&T BoK furthers the initiatives of the NCGIA Core Curriculum, having built upon it and is recognised as its successor (DiBiase et al, 2006). Though it provides guidance on concepts, it has been critiqued due to its focus on "… content mastery rather than who (the learner), what (the intended outcome) and how (the designed teaching and learning process)" (Prager, 2011, p. 67). Foote et al. (2012) also point out "although the BoK suggests developing 'multiple pathways to diverse outcomes,' none were developed for the first edition" (p. 8). To address these shortcomings, a second edition was published in 2010 and a new, quarterly updated version has now been published ('University Consortium for Geographic Information Science: GIS&T Body of Knowledge', 2018), which the researcher has contributed to (Rickles et al, 2017). This new version contains the following new and updated Knowledge Areas:

- Foundational Concepts
- Knowledge Economy
- Computing Platforms
- Programming and Development
- Data Capture
- Data Management
- Analytics and Modeling
- Cartography and Visualization
- Domain Applications
- GIS&T and Society

This version of the GIS&T BoK was not available at the time of this research, though, so the GIS&T BoK as revised in 2010 will be the BoK referred to throughout this report.

2.4.6 Japan Standard GIS Core Curriculum

The Japan Standard GIS Core Curriculum was initially being established in 2009 by the efforts of two projects:

- "Development of Curricula for Geographic Information Science and a Sustainably Collaborative Web Library System for Serving the Materials of the Curricula" (2005-2008) (lead researcher, Atsuyuki Okabe [University of Tokyo]) (Okabe, 2008)
- "Establishment of Education Methods of Geographic Information Science: How to Teach GIS at Universities Effectively" (2005-2009) (lead researcher, Yuji Murayama [University of Tsukuba]) (Murayama, 2007).

From these projects' results, two groups of GIS education emerged – one more focused on Geography and the other more on Computer Science/Information Technology with the following eight sections of topics:

- Introduction
- Modelling and Spatial Concepts of the Real World
- Spatial Data Types and Structure
- Acquisition and Creation of Spatial Data
- Spatial Data Transformations and Management
- Visual Communication of Spatial Data
- Spatial Data Analysis
- GIS and Society

These topics then further subdivide into 41 basic, 116 intermediate, and 120 specific topics. The themes of Geographic Principles, Geographic Data Handling Techniques, Geographic Analysis and GIS Management still appear to be a part of this curriculum, given the sections on Modeling and Spatial Concepts of the Real World, Acquisition and Creation of Spatial Data, Spatial Data Analysis and GIS and Society, respectively. However, since the completion of these projects, little work has been carried out nor has there been further work on the two groups (Geography and Computer Science/Information Technology) or cross-overs between them by the initial research team (Kawabata, Thapa, Oguchi & Tsou, 2010; Sasaki, Oguchi, Okabe & Sadahiro, 2008).

2.4.7 A Comparison of the Curricula in an IDR Context

Though they may differ, what may be seen from them is that these curricula have all been carefully constructed to try and meet the needs of learners. Table 2.4 summarises all the curricula covered, their structure and continued development, their coverage of the themes identified in Longley et al (2010) and their potential suitability for IDR, bearing in mind the previously identified IDR challenges (Table 2.1) and suggested solutions (Table 2.2). Most seem to cover the main themes from Longley et al (2010), though the Geographer's Craft Project and the Revision of Berry's Geographic Matrix do not appear to explicitly cover some. The Geographer's Craft Project and European GIS Curriculum do offer possible advantages for adult education, by incorporating problem oriented learning techniques and targeting postgraduate adult learners respectively; however, both are no longer being developed. Similarly, the Revision of Berry's Geographic Matrix for GIS and the Japanese Standard GIS Core Curriculum have not been developed beyond the articles initially outlining them and the NCGIA Core Curriculum has been succeeded by the GIS&T BoK.

With the GIS&T BoK potentially being of interest for the continued research of this report, it may be necessary to compare it to the other discussed curricula to justify its use.

Table 2.5 compares the concepts from the other curricula reviewed in the previous section to the GIS&T BoK Knowledge Areas. What can be seen from this is that concepts from Data Manipulation and Geocomputation are often not part of the other curricula, nor are their topics as comprehensive in coverage as the GIS&T BoK. The Japan Standard Core Curriculum comes close; however, the GIS&T BoK still has many more topics and learning objectives. Though it was not available at the time of this research, the new GIS&T BoK was also included in Table 2.5 to show how its new and updated Knowledge Areas compare to the original GIS&T BoK. As such, because it is the recognised successor of an internationally successful GIS curriculum, its comprehensive coverage of topics, continued development and modular learning approach, which may be conducive to IDR, the GIS&T BoK may be the most appropriate curriculum for the research of this report and will therefore be used to frame GIS concepts.

Table 2.4 GIS Curricula, Coverage of GIS Concepts and their Suitability with respect to IDR Challenges/Suggested Solutions

Curriculum	Structure and Continued Development	Topics Covered	Suitability to IDR Project (challenges/solutions)
NCGIA Core Curriculum (1991)	Standardised one-year course; 75 one-hour units. Revised in 2000; no further updates.	Coverage of Geographic Principles, Geographic Analysis, Geographic Data Handling Techniques and GIS Management	"Time Constraints" is an issue due to length of the course. Individual units could be delivered, but not structured that way and may rely on material in other units that may not be included.
The Geographer's Craft Project (1992)	Open source access to materials (audio, video, etc.); development stopped after 1996.	Coverage of Geographic Principles, Geographic Analysis and GIS Management; however, Geographic Data Handling Techniques not clearly defined.	Will not adequately "Provide Training on Technical and Supplemental Skills", as materials are out of date, though general media could still possibly be used.
European GIS Curriculum (1993)	Three part post-graduate GIS course; further work abandoned after 1996.	Coverage of Geographic Principles, Geographic Analysis, Geographic Data Handling Techniques and GIS Management	Principles may be used but may not adequately "Provide Training on Technical and Supplemental Skills" if concepts have been deprecated.
Revision of Berry's Geographic Matrix for GIS (1995)	General overview of 10 approaches to understanding space to tailor education efforts; no further work beyond 1996.	Coverage of Geographic Analysis; however, not clear if Geographic Principles, Geographic Data Handling Techniques or GIS Management are adequately covered.	Broad overview – distilling finer points and compiling pointed materials may impact "Time Constraints", but may help appropriately align topics with intended learning outcomes when "Providing Training on Technical and Supplemental Skills".
GIS&T BoK (2006)	Recognised as the successor of the NCGIA Core Curriculum, made up of 10 Knowledge Areas, 73 units, 329 topics and over 1600 formal educational objectives. Revised in 2010 and new GIS&T BoK published with quarterly updates.	Multiple topics that cover Geographic Principles, Geographic Analysis, Geographic Data Handling Techniques and GIS Management	Modular and customisable; should not impact "Time Constraints", much, as materials are already compartmentalised. This can pointedly fill the gap between disciplines that leads to "Difficulties Related to Collaborating with Other Disciplines" while "Providing Training on Technical and Supplemental Skills" and helping "Build Relationships with Members of the Group". Specific topics can be used to adequately address "Difficulties Related to Collaborating with Other Disciplines" and minimise impacts on "Time Constraints". Using these topics to "Provide Training on Technical and Supplemental Skills" can

			help “Build Relationships with Members of the Group”. Worrying, though, as little work has been carried out beyond 2010 to improve upon findings; begs the questions of further refinement and continuity.
Japan Standard GIS Core Curriculum (2009)	Two tracks – more Geography or more Computer Science/Information Technology focused; 8 sections, 41 basic, 116 intermediate, and 120 specific topics. Little work carried out beyond 2010.	Coverage of Geographic Principles, Geographic Analysis, Geographic Data Handling Techniques and GIS Management	Specific topics can be used to adequately address “Difficulties Related to Collaborating with Other Disciplines” and minimise impacts on “Time Constraints”. Using these topics to “Provide Training on Technical and Supplemental Skills” can help ”Build Relationships with Members of the Group”. Worrying, though, as little work has been carried out beyond 2010 to improve upon findings; begs the questions of further refinement and continuity.

Table 2.5 Comparison of GIS Curricula to GIS&T BoK

Geographic Information Science and Technology Body of Knowledge – Knowledge Areas

	Analytical Methods	Conceptual Foundations	Cartography and Visualization	Design Aspects	Data Modeling	Data Manipulation	Geo-computation	Geospatial Data	GIS&T and Society	Organizational and Institutional Aspects	Comments
NCGIA GIS Core Curriculum	Introduction to GIS (F), Technical Issues in GIS (K)	Introduction to GIS (G), Technical Issues in GIS (M), Application Issues in GIS (S)	Introduction to GIS (F), Technical Issues in GIS (K,N)	Introduction to GIS (D), Application Issues in GIS (Q,R)	Technical Issues in GIS (L)	Technical Issues in GIS (H)	Technical Issues in GIS (I,J)	Introduction to GIS (B,C,E), Technical Issues in GIS (H)	Application Issues in GIS (P,S)	Application Issues in GIS (O,S)	Comprised of 75 one hour units
The **Geographer's** Craft Project	Term 1 (Research Concepts and Exploratory Data Analysis)	Term 1 (Research Concepts and Exploratory Data Analysis), Term 2 (Questions of Accuracy and Precision and Managing Error)	Term 1 (Principles of Cartographic Communication, Overview of WebGIS, Principles of Hypertext Design and Publishing), Term 2 (Overview of WebGIS, implementation of WebGIS)	Term 1 (Project Planning and Data Sources for GIS)	Term 1 (Database Concepts and Design), Term 2(Three-dimensional Modeling)			Term 1 (Issues in Demographic Mapping, Project Planning and Data Sources for GIS, Coordinate Systems), Term 2 (Coordinate Systems)	Term 2 (Economic and Legal Relating to GIS and Other Information Technologies, Ethical Issues Relating to GIS and Other Information Technologies)	Term 2(Trends in GIS Technologies and Presentation of Final Projects)	General introduction given; interwoven contextual learning activities; inclusion of topics on CAD and animation
European GIS Curriculum	Part Two - Information Systems for GIS (12)	Part One - Spatial Information for GIS (1,2,3,6)	Part Four - Using GIS in the Organisation (14)	Part One - Spatial Information for GIS (7), Part Two - Information Systems for GIS (8,9,10,11,13)	Part One - Spatial Information for GIS (3), Part Two - Information Systems for GIS (10)			Part One - Spatial Information for GIS (2,5), Part two - Information Systems for GIS (11)	Part Four - Using GIS in the Organisation (15,18)	Part Four - Using GIS in the Organisation (16,17)	General introduction given; interwoven course project
Revision of **Berry's** Geographic Matrix for GIS	Study of spatial covariations or spatial associations; The study of changing spatial distribution; The study of the changing character of some particular	The study of spatial distributions and maps; The study of localized associations of variables in place, and to locational inventories; Study of spatial covariations	The study of spatial distributions and maps					The study of localized associations of variables in place, and to locational inventories; Study of areal differentiation; The study of areal differentiation in its holistic sense			Concepts are abstract to allow for varied application

	area through a series of stages; The styd of changing spatial associations	or spatial associations; The study of changing spatial distribution; The study of the changing character of some particular area through a series of stages; The study of changing spatial associations									
Japan Standard GIS Core Curriculum	Spatial Data Analysis	Modelling and Spatial concepts of the Real World		Spatial Data Transformations and Management	Modelling and Spatial concepts of the Real World	Spatial Data Transformations and Management		Spatial Data Types and Structure; Acquisition and Creation of Spatial Data	GIS and Society		General introduction given; comprised of 8 topics that subdivide into 41 basic, 116 intermediate and 120 specific topics (in comparison to GIS&T BoK 10 Knowledge Areas, 73 units, 329 topics and over 1600 formal educational objectives)
New GIS&T BoK	Analytics and Modeling	Foundational Concepts; Knowledge Economy; Domain Applications	Cartography and Visualisation	Data Management	Analytics and Modeling	Data Management	Computing Platforms; Programming and Development	Data Capture; Data Management	GIS&T and Society	GIS&T and Society	10 Knowledge Areas with units and topics that are new or renamed/merged ones from the original GIS&T BoK; living document that is added to/updated quarterly

2.4.8 GIS Professional Competency Frameworks

Outside of GIS curricula, a variety of sources outline skills those working in geospatial industries should have. LeGates (2009) proposes that urban planners have certain core geospatial skills and software competencies, with specialisations – land use planning, environmental planning, transportation planning and urban design – requiring a further subset of competencies. LeGates, Tate and Kingston (2012) reviewed this as well as other sources identifying GIS skills (including the GIS&T BoK) and suggested that urban planners should have three levels of geospatial skills – those associated with generalist spatial thinking (Level 1), core professional spatial thinking education (Level 2) and specialised spatial thinking education (Level 3). Perhaps LeGates's initial work was too prescriptive, which led to later work that could be abstracted. Regardless, this work was influential to the Royal Town and Planning Institute (RTPI) that formalised in their policies that its members must undertake spatial education that covers 13 learning outcomes (RTPI: Policy Statement on Initial Planning Education, 2012), which are as follows:

1. Explain and demonstrate how spatial planning operates within the context of institutional and legal frameworks.
2. Generate integrated and well substantiated responses to spatial planning challenges.
3. Reflect on the arguments for and against spatial planning and particular theoretical approaches, and assess what can be learnt from experience of spatial planning in different contexts and spatial scales.
4. Demonstrate how efficient resource management helps to deliver effective spatial planning.
5. Explain the political and ethnical nature of spatial planning and reflect on how planners work effectively within democratic decision-making structures.
6. Explain the contribution that planning can make to the built and natural environment and in particular recognise the implications of climate change.
7. Debate the concept of rights and the legal and practical implications of representing these rights in planning decision making process.
8. Evaluate different development strategies and the practical application of development finance; assess the implications for generating added value for the community.
9. Explain the principles of equality and equality of opportunity in relation to spatial planning in order to positively promote the involvement of different communities, and evaluate the importance and effectiveness of community engagement in the planning process.

10. Evaluate the principles and processes of design for creating high quality places and enhancing the public realm for the benefit of all in society.
11. Demonstrate effective research, analytical, evaluative and appraisal skills and the ability to reach appropriate, evidence based decisions.
12. Recognise the role of communication skills in the planning process and the importance of working in an interdisciplinary context, and be able to demonstrate negotiation, mediation, advocacy and leadership skills.
13. Distinguish the characteristics of a professional, including the importance of upholding the highest standards of ethical behaviour and a commitment to lifelong learning and critical reflection so as to maintain and develop professional competence.

Similarly, the Chartered Institution of Civil Engineering Surveyors (ICES) requires its members to have geospatial competencies along with discipline related ones (ICES: Geospatial Engineering Competencies – Geographic Information Science, 2011). In comparison, they have outlined specific concepts, which are detailed in Table 2.6.

Table 2.6 ICES: Geospatial Engineering Competencies – Geographic Information Science

Competency	Details
Spatial Data	Metadata, Application of Standards, Transformation / data manipulation, Vector-to-raster and raster-to-vector, Raster re-sampling
Data Modelling	Vector Data Models, Geometric primitives, Spaghetti model, Topological model, Network model, Linear referencing, Tessellation Data Models, Grid representation, Raster model, Triangulated Irregular Network (TIN) model
Spatial Analysis and Processing	Basic Analytical Operations, Buffers, Overlays, Neighbourhoods, Map Algebra, Analytical Methods, Surface Analysis, Network Analysis, Cartographic Modelling, Spatial Queries and Measures, Distance & lengths, Shape, Area, Proximity, Adjacency, Connectivity, Intervisibility, Structured Query Language (SQL) and Attribute Queries, Aggregate data, Group by and order clauses, SQL Join, Geographic analyses, Geostatistics, Geocoding, Direct (X,Y), Indirect (e.g. post code)
Visualisation	Map, Thematic, 3D Drape, View shed, Fly through, Time series
Software and Initiatives	GIS Software, Open Geospatial Consortium (OGC) software, Open Source Geospatial Foundation, Geospatial libraries, Desktop applications, Web mapping, Servers, Geospatial Initiatives, Digital National Framework, Inspire, Making Public Data Public
Technologies – GIS Software Development	Software Development Concepts, Development Environment, Integrated Development Environment (IDE), Menu Bar, Toolbar, Project explorer, Properties, Editing, Compiling, Linking modules into projects, Debugging, Fundamentals / Conditions, Variables, Expressions, Looping, branching and flow-control, Procedures, Functions, User Interface/controls, Menus, Forms, Controls, Object

	Processing, Object Variables, Querying objects, Creating new objects, Modifying objects, Layer Processing, Reading from, Writing to, Creating, Modifying, Accessing remote databases, File Processing, File input/output, File creation, copying and deletion
Technologies – Database Development	Database Management Systems (DBMS) Concepts, Co-evolution of DBNS and GIS, Relational DBMS, Object-oriented DBMS, Spatial databases, Database Development Concepts, Understand and demonstrate the concepts behind database development, Tables, Fields, Indexing, Relationships, User Interface/controls, Menus, Forms, Controls, Fundamentals/Conditions, Variables, Expressions, Looping, branching and flow-control, Procedures, Functions, Object Processing, Object variables, Querying objects, Creating new objects, Modifying objects

Particularly intended for GIS professionals, the Geospatial Technology Competency Model (GTCM) was developed by the United States Department of Labor (DiBiase et al., 2010). This model has five tiers, which focus on the following:

- Tier 1: Personal Effectiveness Competencies – Interpersonal Skills, Integrity, Professionalism, Initiative, Dependability and Reliability, Lifelong Learning
- Tier 2: Academic Competencies – Reading, Writing Mathematics, Geography, Science and Engineering, Communication – Listening and Speaking, Critical and Analytical Thinking, Basic Computer Skills
- Tier 3: Workplace Competencies – Teamwork, Creative Thinking, Planning and Organising, Problem Solving and Decision Making, Working with Tools and Technology, Checking, Examining and Recording, Business Fundamentals
- Tier 4: Industry-Wide Technical Competencies – Core Geospatial Abilities and Knowledge (Earth Geometry and Geodesy, Data Quality, Positioning Systems, Remote Sensing and Photogrammetry, Cartography, GIS, Programming, Application Development and Geospatial Information Technology, Professionalism). Also embedded in this tier are the GIS&T BoK KAs.
- Tier 5: Industry-Sector Technical Competencies – Positioning and Data Acquisition, Analysis and Modelling, Software and Application Development

Bearing the concepts of these suggested skillsets in mind, Error! Reference source not found. maps them to the GIS&T BoK KAs. From what can be seen, again the GIS&T BoK KAs show comprehensive coverage of topics, including those that may not be included by these frameworks, further supporting its appropriateness for application with learners in academic and commercial settings.

Table 2.7 Comparison of GIS Professional Competencies to GIS&T BoK

Geographic Information Science and Technology Body of Knowledge – Knowledge Areas

	Analytical Methods	Conceptual Foundations	Cartography and Visualization	Design Aspects	Data Modeling	Data Manipulation	Geo-computation	Geospatial Data	GIS&T and Society	Organizational and Institutional Aspects	Comments
RTPI	11	5, 7							2, 3, 5, 6, 7, 8, 9, 10	1, 4, 8, 12, 13	Largely focused on conceptual, organisational and societal aspects. Coverage of specific geospatial topics left to institution programme design
ICES	Spatial Analysis and Processing	Spatial Data	Visualisation		Data Modelling, Technologies – Database Development	Spatial Data		Spatial Data		Software and Initiatives	Topics associated with Technologies – GIS Software Development largely not included in current version of GIS&T BoK
GTCM			Tier 4: Cartography					Tier 4: Earth Geometry and Geodesy, Data Quality, Positioning Systems, Remote Sensing and Photogrammetry		Tier 4: Professionalism	Tier 4 concepts around Programming, Application Development and Geospatial Information Technology not included in current version of GIS&T BoK; however, BoK itself is included in Tier 4.

2.5 Summary

In this chapter, literature was reviewed on the topics of IDR, educational approaches and GIS concepts framed by formally structured curricula. Individually, adequate coverage of these exists; however, their overlaps and the nexus between the three topics are still under-researched areas. There are many IDR studies that have used GIS, which were mentioned in Chapter 1 and will be discussed in greater detail in Chapter 3; however, a comprehensive review of these has yet to be conducted so it may be understood how GIScientists could guide on the use of GIS to maximise its positive impacts in these projects. There has been some research into various educational practices with GIS (Bednarz, 2000; Kerski, 2003; King 2008; Drennon, 2005), but many articles on this are over ten years old. In general, studies around educational practices in IDR, when published on, are submitted to discipline-specific journals; as such, centralised resources that could provide understanding of interdisciplinary education do not readily exist. At the time this work was undertaken, no other researchers were known to be specifically investigating how to improve the GIS learning experience for interdisciplinary researchers. As such, the outputs of this report fill knowledge gaps and may help advance understanding in areas that required further exploration.

The lack of studies and guidance presented difficulties, particularly with regard to understanding the experience of interdisciplinary education. Interdisciplinary researchers will go through a learning journey in a real-world setting, when learning new tools. That experience could be said to be similar for students going through interdisciplinary courses and programmes that need to quickly learn methodologies and apply them in course or group work, delivering to a certain standard and deadline. Though these may be more formally structured, students will still have a gap of understanding that will need to be bridged that may be difficult, depending upon how unfamiliar the tools and methodologies are in comparison to their home discipline as well as how effectively students learn them. Therefore, if interdisciplinary researchers prove difficult to engage with, interdisciplinary students may act as a proxy for exploring GIS learning. The formal educational setting may also provide benefits to focus investigation on topics of interest, such as specific GIS concepts and disciplinary jargon. This was this case for this research, which is explained in 7.2 Interdisciplinary Learning Opportunities for GL4U.

Considering the topics covered in this chapter on IDR, educational approaches and GIS concepts, it can be seen that there are common IDR challenges and suggested solutions throughout the literature; however, most are theoretically proposed and have not been practically investigated in real-world case studies. Regardless, they give a good framework, to start, and, due to frequency of occurrence of individual elements in the literature, imply that “Difficulties Related to Collaborating with Other Disciplines” is the most common challenge and “Provide Training on Technical and Supplemental Skills” as the most often suggested solution, but how does this apply in practice?

Educational approaches have evolved over time to improve the effectiveness of teaching and learning. Contemporary theories believe that the focus should be on the student, creating the appropriate environment and facilitating the learning they wish to achieve. Adult learners are self-directed and self-motivated; as such, the learning environment must be seeded with thought-provoking and relevant material. CBL may be able to achieve this, as the literature suggests it is appropriate for this audience. Therefore, could CBL be used to structure learning resources most effectively for adults involved in IDR, to understand tools/methodologies outside of the researchers’ own discipline?

The structure of GISc education itself has gone through a process of refinement and reinvention at various times across in different parts of the world. The NCGIA Core Curriculum, which initially set a global standard, has been replaced by the more contemporary GIS&T BoK, which has merit for a wide variety of applications, given the multitude of Knowledge Areas and their subsequent subdivisions. The concepts contained within are what practitioners in the field of GISc believe those who are entering it should know; however, how applicable are those concepts to those who simply wish to use a GIS? Which concepts do people, such as interdisciplinary researchers, need to know in order to adeptly use the GIS to accomplish the goals of their work?

In summary, “Difficulties Related to Collaborating with other Disciplines” is common in IDR and may be avoided through “Providing Training on Technical and Supplemental Skills”. Though there are many approaches to learning, CBL appears to be one that may be complementary to IDR. From existing GIS curricula, the GIS&T BoK not only continues to be developed, but also frames concepts in a modular and comprehensive fashion. Together, these elements may be used to construct better GIS learning resources and opportunities for interdisciplinary researchers. Therefore, the focus of this report will be on the empirical testing and review of these concepts.

Chapter 3 - Preliminary Case Studies, Gap Analysis and Research Questions

As has been established, interdisciplinary researchers have a number of challenges they may face, with some suggested solutions for overcoming those issues. One of the challenges identified is “Time Constraints”; bearing this in mind with respect to the solution of “Providing Training on Technical or Supplementary Skills”, though the interdisciplinary researcher may wish (or need) to learn how to use a GIS, they may not have a large amount of time to learn to do so. This may mean that they use an unstructured, experiential learning approach, such as informal learning, to try and learn what they need to learn; however, this may not be the most efficient approach if they cannot clearly define the problem they wish to solve with the GIS. Even if they were to understand that, though, in order to learn how to do what they want to do, they may only need to cover some GIS concepts, such as those around handling and analysing data, and can perhaps avoid delving into the intricacies of GISc principles or GIS management. However, it is a cyclical problem; without knowing which concepts they need to learn to find learning resources that teach them how to do what they want to do in the GIS, researchers may spend a large amount of time fruitlessly searching for information.

To try and expedite learning, GIS professionals have created training programmes, in which some attempt to loosely implement parts of curricula that have been deemed important, with the aim of introducing students to the aspects relevant to their intended use of geospatial software in a short amount of time. For example, GIS software vendors generally offer short courses relating to the use of their products (1-week basic courses extending to 1 or 2 months for advanced learning). This may provide a collaborative learning opportunity for an IDR team, helping to establish mutual exchange amongst team members and “...develop the requisite insights into the perspectives of one another’s disciplines...” (Newell, 1992, p. 215). Therefore, an adequate amount of time should be set aside for interdisciplinary training opportunities (Nash, 2008, p. S138), which should be used to learn tools from the different disciplines involved in the IDR project, such as GIS. With that said, though, such opportunities may be expensive and might not provide in-depth coverage of underlying concepts necessary to fully utilise GIS (Weber, Ellul & Jones, 2012).

Therefore, it may be suggested that the programme of work for the project be properly understood to determine if a training programme is affordable and sufficient for the research purposes or if further, in-depth knowledge of GISc is necessary for achieving the project goals. If it is the latter, a GIScientist with understanding of IDR will likely need to be involved to identify what needs to be learned and to suggest or create learning materials. Researchers with such skills may be difficult to find, so in absence of that, learning resources should be comprehensive, yet precise and relevant. The determination of that balance continues to be an under researched area, which this work has sought to address.

Without a way of establishing accelerated uptake of GIS, researchers on interdisciplinary research projects that use it cannot begin to quickly add what they need of it to the methodologies from their own disciplines, perhaps hindering their research. This could majorly impact interdisciplinary analyses and project goals may not be met within the given time frames. It is therefore of great importance that efficient and effective methods for learning GIS be established specifically for researchers involved in interdisciplinary projects.

From the literature review in the previous chapter, certain themes have emerged around interdisciplinary research (IDR), educational approaches and Geographic Information System (GIS) curricula. To guide the further work of this report, the researcher explored these topics through practical work with IDR projects in which they were actively involved. Though it should be noted that that there are potential dangers of the investigator influencing or biasing results from being personally attached to work, (Kientz & Abowd, 2008), there are benefits that must also be considered. Given that they directly participated, the researcher was not considered a stranger and so team members behaved as they normally would (Johnson et al., 2012). The research, utilising this internal perspective, was therefore able to adjust the research design and interpret feedback from participants (Johnson et al., 2012).

Summarising the case studies, the first one allowed the researcher to explore the concept of geospatial metadata while working on the Adaptable Suburbs project. The second one was an exploratory workshop the researcher conducted with the Extreme Citizen Science (ExCiteS) research group, of which they were a member, to get practical insights from other interdisciplinary researchers. The third one was teaching the researcher did for the Development Planning Unit to help interdisciplinary students learn GIS for their field work. These will be discussed in greater detail in the following sections.

3.1 Adaptable Suburbs

Adaptable Suburbs was an interdisciplinary research project that brought together Historians, Anthropologists, Architects and Geographic Information Scientists

(GIScientists) to investigate how four of London's suburbs have evolved over time, and how they continue to be shaped, to accommodate the needs of the people who live there. The team comprised a mix of research students and junior and senior academics, some of whom were already familiar with GIS.

Though researchers from each discipline had their own disciplinary methodologies they wished to use to address the projects questions, GIS was used as a common tool by them to answer the overall questions of the project. Their work has offered a first insight into the research sub-question on "What are some of the learning approaches people involved in IDR have used to learn GIS?" through how they learned to apply GIS and explore the concepts of geospatial metadata. GIS for this project was to be used to compile information on historic business directories to compare to present day establishments, perform a historical reductive network analysis to identify the persistence of roads throughout time and measure the integration and connectivity of streets between each other to estimate how people move through a network. Source files and resulting datasets would need robust metadata stored on them to relay information on currency, accuracy and accountability for analytical purposes.

3.1.1 Methodology

Members from the project team (two anthropologists and an urban researcher, all PhD students) were introduced to the importance of data management for the project, data as a resource and project legacy and an online system for metadata management. Their use of the system to create appropriate metadata for the project's data was to be monitored over a period of a year.

In order to test traditional approaches to GIS learning, classroom based teaching was used to convey GIS concepts to the members of the team. Specifically, concepts relating to spatial data management and metadata (which describes data quality) were taught via a formal lecture (using a series of PowerPoint slides) followed by a hands-on practical session where the researchers could create metadata. This topic was chosen as the project is very data intensive with all members of the team generating datasets using GIS tools, and thus having the required in-depth knowledge of the datasets in order to document and curate them appropriately. In addition, although they may not be aware of it, the research team were all familiar with metadata in the form of academic citation, or musician, conductor and band information for their favourite tracks.

Learning and becoming familiar with GIS was easier for some rather than others on the project; though certain concepts about GIS were recognised as important (e.g. creating and maintaining metadata), they were largely disregarded – only those relevant to the completion of necessary tasks were focussed on. The identification of interdisciplinary issues and GIS concepts of interest would prove to be enlightening for shaping this research.

3.1.2 Outcomes

In the context described above, formal teaching of metadata concepts and tools met with mixed success. While the researchers stated that they understood the importance of the task, and could use the tools, this did not translate into the on-going metadata capture required by the project, even when the importance of the task was clearly stated by the Principle Investigator on the project, and clear deadlines set for the completion of the work. Potentially, many of the IDR-related issues described in 2.1 The Current State of Interdisciplinary Research contributed to this issue. However, in reality issues relating to time and difficulties when collaborating with other disciplines dominated. The time required to create good quality metadata proved to be a problem, in particular when coupled with the fact that this was perceived to be a low-priority task by the researchers (i.e. problems were caused by being at the interface between disciplines with the task not related to the specific discipline of the researcher).

Adding to the discipline-related issues, unlike on a standard GIS training course or degree, concepts relating to spatial metadata were taught in isolation of any other formal GIS training, due to time constraints. Metadata and similar concepts are perhaps difficult to understand in isolation of a greater understanding of the potential GIS-based analysis (e.g. interpolation, networking, neighbourhood analysis) that could be conducted using the curated spatial data, and the impact on this analysis of data quality. Presenting this, or other, topics in isolation complicates the learning process.

In an attempt to address the issues, around six months after the initial training session a number of fortnightly meetings were held where students completed metadata under the supervision of an expert user. However, for the most part, the metadata for the project was created by the GIS team, meaning that extensive dialogue was required between this team member and those who actually captured the data in order to extract the required detailed data description.

3.2 Extreme Citizen Science (ExCiteS)

The Extreme Citizen Science (ExCiteS) research group brings together Artists, Psychologists, Computer Scientists, Geographers, Transport Specialists and other disciplines working on a diverse range of projects all over the world. Some examples are mapping areas around London where people feel fearful, sharing information on noise and air pollution to see if it changes people's habits and collecting information with non-literate populations to identify locations with important resources. The common thread between these is that they are 1) focussed on public engagement, 2) interdisciplinarity and 3) use GIS or geospatial technologies to create, store and visualise information for informed decision-making.

GIS provides ExCiteS researchers the potential to integrate data from a multitude of sources and the wide range of countries covered by the projects. However, technical and GIS expertise in the team varies widely, with some team members being experts and others not very familiar with concepts beyond creating a map. Their feedback has offered a first insight into the research sub-question on "What challenges do people face in interdisciplinary research and how is it suggested that they solve those issues?" Given the experience of this group, they were presented with identified IDR challenges and suggested solutions to understand their relevance in actual IDR projects.

3.2.1 Methodology

The preliminary outcomes from work with the Adaptable Suburbs group highlights the complexity of achieving effective teaching and learning in an IDR setting. To complement this work, a one-off workshop was held with members of ExCiteS to ask about their experiences in IDR. They were first presented with general challenges to IDR projects, which were introduced in 2.1 The Current State of Interdisciplinary Research, and asked to provide their views on how these challenges impacted team members' learning of GIS concepts and tools as required by the projects on which they are engaged. Afterwards, they were then presented a series of proposed solutions to IDR challenges, also identified in 2.1 The Current State of Interdisciplinary Research, and asked for their feedback on these with respect to their experiences of learning GIS. Finally, they were given the opportunity to add any challenges or suggested solutions they felt were not covered in the ones presented to them.

3.2.2 Outcomes

As researchers in this team came from a wide range of backgrounds, they noted that a regular challenge they faced was to bridge the gaps of knowledge between their disciplines. There may be fewer methodological differences between those coming from more closely related disciplines (e.g. Human or Physical Geography); however, when disciplines are very different (e.g. Mathematics and Fine Arts), there is more that is unfamiliar to one researcher about the other researcher's discipline and vice versa. Researchers commented, though, that disciplines methodologically closer to each other had their own tensions, as similar concepts and terms may have different meanings in the other discipline or may be in direct conflict with one another. One noted example was the need for separation of groups of participants to avoid them influencing each other as part of Randomised Control Trials by Psychologists, which impeded the ability for Anthropologists to engage in Participatory Action Research, where anyone who wishes to participate must be invited to do so.

Bridging these gaps or establishing a communally understood way of working together can take some time and ExCiteS researchers stated that they often they did not have adequate time to properly do so. Training on foreign tools and methodologies was of interest to group members; however, given time pressures and limited funds, they did not often pursue any formal education options – they largely learned what they needed to, when they needed to through informal approaches (e.g. internet search, watch a video, ask a more experienced person). Regardless, the relationships and rapport built between team members made them feel comfortable that if there was anything that they did not understand, they felt they could ask each other questions.

Both the preliminary investigation into teaching metadata concepts and usage with Adaptable Suburbs and the subsequent discussion with the ExCiteS team highlights the fact that any teaching/learning approaches selected within an IDR context need to make the best use of limited available time, and take advantage of, or perhaps even contribute to, relationship building within the team. Importantly, they should also take into account the fact that concepts and tools are presented in isolation of a broader foundation in GIS, and that learning takes place in between other, potentially higher priority, tasks. This contradicts a general requirement for education to build on principles familiar to the student, present concepts in a structured manner, ensure materials facilitate engagement in different ways, and take account of different skills to allow students to work at their own pace (Ellul, 2012, p. 451).

3.3 Development Planning Unit (DPU)

Another example of learning GIS in IDR is that of the lectures that were given at the Bartlett School of Graduate Studies' Development Planning Unit (DPU) to educate graduate students on the Environment and Sustainable Development programme on how to use GIS. The DPU focuses on research projects in developing countries and attempts to incorporate a holistic approach in planning and engagement with people. Their research projects often incorporate students from their programmes, making a major case study that students work on throughout their programme; for the years this group was engaged with, their focus was on issues that occur relating to water access rights for people in Lima, Peru framed around a topic of interest (e.g. Agribusiness, Mining, etc.). Students on this programme came from a wide variety of disciplines (Political Science, Urban Planning, Sociology, as well as others) with each student group formed to incorporate the diversity of perspectives.

Realising that reading legislature and talking to stakeholders was not enough, the DPU introduced mapping as an element to their course, to understand that other variables can impact these injustices. GIS was a tool, amongst others, that students could learn, through lectures and optional training sessions coordinated by the researcher, and apply to their topic and include its outputs as part of the group's final report. Using mapping for analysing water access rights in Lima, students can understand how industries can pollute waterways, identify that those with means are getting more than their fair share of water, or that agribusiness can heavily tax local water supplies. Work with the DPU has offered a further insight into the research sub-question of "What are some of the learning approaches people involved in IDR have used to learn GIS?" The students' initial engagement in and with GIS provides not only evidence of how those from other disciplines first approach GIS but also the innovative ways they wish to apply it, further highlighting GIS concepts relevant to interdisciplinary researchers.

3.3.1 Methodology

Structure of teaching basic GIS concepts was derived from the main proposed curricula in GISc, which are detailed in 2.4 Geographic Information Systems Education. Topics to be covered in the first practical included interface familiarisation, navigation, vector and raster data, symbology and cartographic elements and the second one covered georeferencing, projection systems, and queries.

The seminar was one lecture and two practicals delivered over two days. It had to be assumed that students had unknown familiarity with technology and were complete GIS novices. The first day of the seminar started with a simple exercise, where people were divided into groups focusing on a particular water management issue (e.g. Agribusiness) and, with tracing paper, colouring pencils and stickers, copied information from various maps printed of the region that were placed around the room by tracing relevant features, such as rivers, farms, and human population information. In the afternoon, a lecture was given on the importance and various applications of GIS followed by the first practical, which built off the maps the students made earlier, and was about transferring the information they physically traced to the digital medium via GIS.

3.3.2 Outcomes

From the activity on the first day, to use the Agribusiness group as an example, they could then begin to tell the story of how Agribusiness taxes water supplies due to their distance from water sources, the amount of water needed to grow the crops they produce, and how many nearby human settlements are potentially affected. By doing this exercise, students were inadvertently learning, in a simple way, about vector data (points, lines, and polygons), layers of information, and attributing data (as they were also making annotations on the map). For the first practical with the GIS, topics were covered in an abstract and generic fashion, such as of creating points, lines, and polygons, but it was difficult for students because they did not see their information in these conceptual ways – they saw that point as a mine, and that line as a river, or that polygon as a farm. The second practical was the following day and was structured in a more concrete manner, where students were given datasets of information specific to issues in Lima and systematic instructions on how to process and manipulate the data, with images and illustrations to follow, should they get lost.

Overall, the exercise, lecture, and practicals were well received. Students appeared to be engaged and showed enthusiasm in the subject matter, as the outputs of the activity were relevant to the larger problem the students were tasked with handling as part of their course. The first exercise, which was outside of the digital environment, allowed students to establish, as a group, what the problem was, identify their priorities, and compile pertinent layers of information, without the added difficulty of having to do so at the same time as learning a piece of technology they may not be familiar with, which poses its own challenges. Afterwards, with the consensus of ideas recorded on the physical map, they were able to work together in the first practical to transfer the information to the GIS, and help each other out with the task of doing so, with guidance when needed from available teaching staff. To combine the activity and traditional approaches, additional theory was delivered between activities by a lecture, to provide necessary context for the use of a GIS.

3.4 Gap Analysis – Adaptable Suburbs

The nuances of each of the preliminary case studies may be further explored with respect to learning approaches, GIS concepts and interdisciplinary issues. Beginning with Adaptable Suburbs and the metadata task, as researchers were presented the concepts of geospatial metadata, albeit in a different context to what they were already familiar with (e.g. metadata on academic citations, music, etc.), the team were learning about this kind of metadata via a Constructivist approach, building knowledge through understanding of existing knowledge. As this was completed collaboratively, this may further be considered Social Constructivism. Also bearing in mind the various Knowledge Areas (KAs) of the Geographic Information Science & Technology (GIS&T) Body of

Knowledge (BoK), metadata is part of Geospatial Data; though teaching dynamics for this are laid out, they were not taken into account due to this work being undertaken before familiarity with the GIS&T BoK. The Geospatial Data KA, however, should be noted as being of importance to the team's work.

This work also highlighted a number of the challenges of IDR, in that because of "Difficulties Related to Collaborating with Other Disciplines" (i.e. the gap of knowledge in understanding the importance of metadata to GISc and the GIS work that was to take place during the project), "Time Constraints", and/or a "Lack of Local Level Management" (to follow up on the production of metadata more regularly), the work was not completed. From the suggested IDR solutions, "Providing Training on Technical and Supplemental Skills" (or at least in the way that it was delivered), was attempted, but not successful.

Reflecting on this experience, the research team may have been better engaged by being set a problem of selecting appropriate datasets to solve a research challenge related to the project, from a variety of available sources. Engaging in such a task provides both the interdisciplinary learning opportunity and the teambuilding that has been suggested from the literature for IDR projects ("Provide Training on Technical and Supplemental Skills" and "Build Relationships with Members of the Group", respectively). Had the learning materials also been tailored to the project more specifically, rather than on geospatial metadata in general, this may have increased the likelihood of uptake and follow-through for the task. With such a Context Based Learning (CBL) approach, concepts learned could have been translated and applied to outputs that directly contribute to the project. Those creating the educational materials who were involved with the research, could have better assessed the researchers' specific learning needs and to adjust learning programmes as necessary to fit within the researchers' limited available time. Intertwining other relevant concepts from the GIS&T BoK Knowledge Areas may have also been better for engaging the researchers, so it was not just Geospatial Data concepts, but also included Analytical Methods to understand the geoprocessing work that was to be carried out on the project. This would have better impressed upon the team the relevance of the metadata and the necessity of its creation. This matter, as well as further GIS complications were explored by Rickles & Ellul (2014b).

3.5 Gap Analysis – ExCiteS

The feedback from the ExCiteS team has provided further understanding of IDR issues. Though this may not be considered a traditional, lecture/practical learning situation, by sharing their opinions in a (safe) environment with their fellow team members, this could be said to engage in a Humanistic Approach to learning, as the discussion was centred around them and they could learn from each other. GIS concepts, as related to the GIS&T BoK KAs were not part of the discussion, as GIS was talked about in general (use vs. non-use and difficulties encountered).

With respect to the IDR challenges and suggested solutions, the comments from ExCiteS researchers seemed to mirror the findings from the geospatial metadata activity with the Adaptable Suburbs researchers. Members of the ExCiteS group identified “Difficulties Related to Collaborating with Other Disciplines” and “Time Constraints” to be the challenges that have most affected them in previous and current IDR projects. The team reported that home discipline methodologies, and the nuances in undertaking their analyses, were often not understood by other members of the IDR team and that they did not have enough time to educate them on these distinctions or understand the other disciplines’ confusions with something perceived fundamental to their own.

“Providing Training on Technical and Supplemental Skills” was not considered to always be an ideal solution to the group, given that it would create or worsen existing “Time Constraints”, as members of the team would likely not have the adequate amount of time to devote to training. Indeed, when asked about training in IDR, the team seemed ambivalent and referred back to the challenge of “Time Constraints” – voicing concerns that even if training were available, they would likely not have time to take advantage of it due to other, more pressing obligations. This is particularly the case with senior members of the research team. However, when questioned, “Building Relationships with Members of the Group” was said to be the most useful approach to enable learning in IDR settings, although this view contrasts with that of the literature, which suggests to “Provide Training on Technical and Supplemental Skills”.

This may suggest that training may not be a viable solution in some circumstances, or it is simply perceived to be so. As discussed in 2.5 Summary, though, a structured approach for training, such as one using CBL, may be able to deliver it in a timely and complementary way to an IDR team. This suggests that if training is to be considered viable by an IDR team, it must cover only relevant material within the shortest amount of time necessary to help learners achieve their goals. Outside of the matter of training, the feedback from ExCiteS continues to corroborate the finding that “Difficulties Related to Collaborating with Other Disciplines” is an ongoing issue, as well as “Time Constraints”, and it is interestingly proposed that “Building Relationships with Members of the Group” can help ease any current or future tensions that may arise.

3.6 Gap Analysis – DPU

The work with the DPU has provided the ability to investigate learning approaches, the relevance of GIS concepts and IDR issues. For this traditional classroom, lecture/practical style educational experience, a social constructivist approach was taken. Data were collected and maps were produced in the GIS within preformed groups of students, focusing on a specific concept relating to Environmental Justice (e.g. Access to Water (based on Socio-demographics), Agribusiness, Mining, etc.) that they had already been researching with their group. By using these relevant contexts, learners were able to build understanding on top of existing knowledge, which facilitated learning. Using the GIS&T BoK KAs to frame the GIS concepts, Analytical Methods, Cartography and Visualization, Conceptual Foundations, GIS&T and Society, and Geospatial Data were interwoven within the lectures and practicals.

With regard to IDR issues, the students, who came from different disciplines, seemed to successfully navigate any “Difficulties Related to Collaborating with Other Disciplines”, “Personality Conflicts” or “Problems Being at the Interface Between Disciplines”, as they had been working within their groups for some time now and have “Built Relationships with Members of the Group”. By “Providing Training on Technical and Supplemental Skills”, in this case with GIS, they were further able to see how their disciplines tied together, using it as a medium to facilitate cross-disciplinary communication. Though a number of the GIS&T BoK KAs were touched upon, Geospatial Data and Cartography and Visualization seemed to be the most successfully learned. By focusing on the construction of spatial information and production of maps, as these tasks were part of their group work, students were later able to do these with little difficulty, as reported back by the course tutor.

Perhaps in comparison between the first and second practical, practical one was more of a PBL approach, given that the students were allowed to define the boundaries of the problem and how they would solve it. Perceived difficulties may have been due to the students feeling confusion over the fact that this was not a way of teaching they were familiar with or they may not have had the necessary background in the topics to direct themselves in the problem solving process, and so they required more support from the lecturer. In practical two, a CBL approach was taken, where the problem set for the activity was contextually relevant to learners (specifically created to teach GIS concepts on water access issues in Lima, Peru) and the activity itself was more structured than in the first practical. Students appeared to be more comfortable with this approach and as the compilation of materials were more prescriptive than in the first practical, the teaching exercise went more easily for both the students and the researcher.

3.7 Summary

This preliminary work has provided some insights that may help move towards investigating the appropriateness of using current approaches to GIS teaching within academic IDR projects. As can be seen from these examples and the literature review, though there is interest in working with other disciplines through IDR, there are still a number of issues that need to be overcome. Often there are “Difficulties Collaborating with Other Disciplines” and understanding the how to address the gaps between them. “Time Constraints” are also commonly problematic, given that IDR requires researchers to learn about tools and methodologies from other disciplines, while they also need to advance their own disciplinary goals. If “Providing Training on Technical and Supplemental Skills” is to be a successful solution to such issues it must be short, effective, and fit in amongst higher research priorities. Training may possibly help “Build Relationships with Members of the Group” if it is part of a collaborative learning environment. The teaching method selected for such an IDR learning initiative must allow for immediate application of understanding to relevant problems, for which a CBL approach may be suitable. Finally, GIS concepts from Geospatial Data and Cartography and Visualization within the GIS&T BoK KAs appear to be relevant to IDR, so it might be suggested for learning resources to focus on these.

From the preliminary case studies with ExCiteS and the Adaptable Suburbs project, a number of IDR issues were highlighted that may increase the complexity of the learning task when compared to learning GIS in a classroom setting. Within Geographic Information Science (GISc), classroom based and distance learning approaches have been instituted in many major university programmes, community college certifications and online training courses for formal education (Baker, 2002). However, if GIS is to achieve its potential as a conceptual integrator and useful tool on many IDR projects, alternative methods of learning, which take into account the complexities of IDR will need to be devised. It can be suggested that a “one-size-fits-all” generic training program for GIS in IDR would not be appropriate, but that by bearing in mind what and how knowledge is constructed in active research using GIS, relevant and successful learning techniques can be created.

This preliminary work forms part of an important, and yet under-researched, question on how can learning GIS be improved for interdisciplinary researchers? With the interplay of GIS, educational approaches and IDR in the preliminary case studies explored, the research questions that have emerged from the associated gap analysis may be confirmed, which are as follows:

1. What challenges do people face in interdisciplinary research and how is it suggested that they solve those issues?
2. Which GIS concepts are relevant to people in IDR?
3. Which educational approaches may be relevant to learning GIS and how do they compare to one another?
4. What are some of the learning approaches people involved in IDR have used to learn GIS?
5. Can a contextually relevant mixed formal (institutionally led)/non-formal (loosely organised) learning resource improve uptake and application of GIS in IDR?

The suitability of GIS concepts and tools for IDR may facilitate further exploration of these topics, which the research in this report will investigate. The following chapter will begin to do this by building on these preliminary findings, shaping the continued research, to identify and understand current IDR that has used GIS.

Chapter 4 - Identifying and Understanding Use of GIS in IDR

Geography has been described as a “bridge discipline” that is capable of connecting the study of human and natural systems as well as one capable of intellectual synthesis (Gober, 2000). Similarly, use of Geographic Information Systems (GIS), as a tool of Geography, has expanded because of its interdisciplinary nature, straddling the boundaries of geography, mathematics, literacy, Earth science, cartography, remote sensing, cognitive psychology, biology, computer science, education, and other fields (Baker et al, 2012). The three case studies described in Chapter 3 highlight examples of the use of GIS in interdisciplinary research (IDR) at UCL. It is necessary, though, to look outside of more localised examples to understand how others may be using it, which concepts are of relevance to them and what issues they may have had when using it. By reviewing many experiences, a more holistic understanding of GIS in IDR may be developed and future endeavours may be better supported.

To understand these aspects of learning GIS in IDR, a variety of research methods were employed to gather information. In this chapter, a bibliometric analysis was conducted using screen scraped data (4.1 Google Scholar Analysis) as well as a survey (4.2 Online Survey). The following chapter uses more localised approaches such as interviews (5.1 One-on-One Interviews) and learning diaries (5.2 Learning Diaries).

A bibliometric analysis was selected to review what work interdisciplinary researchers have previously carried out and published. Bibliometrics have been recognised as an indicator of the importance and impact of work and is increasingly used to measure and rank research both within institutions and on a national or international level (Bibliometrics basics, 2018). This type of analysis does have limitations though, around making comparisons to different subject areas, between publications of different ages and associated with citation counts, which may also include self-citations (Bibliometrics basics, 2018). These were taken into consideration; however, this work would fundamentally be looking at how different disciplines used GIS for IDR. As such, it would be comparing articles from different subject areas, though only on the basis of GIS use and IDR related issues. Older publications may have been available longer and as such had more opportunity to be cited than newer ones; however, if the topics covered within the article are perceived to be important to the discipline, it will be cited more frequently regardless of age. Self-citations, though, could not be removed from the extracted citation counts, which must be considered as one of the caveats of this analysis’s outputs.

An online survey was utilised to obtain a structured overview of interdisciplinary researchers' experiences around learning to use and apply GIS. As noted by Ilieva, Baron and Healey (2002), surveys can be a useful approach for collecting information for the following reasons:

- Very low financial resource implications
- Short response time
- Researchers' control of the sample (and no involvement in the survey)
- Data are directly loaded in the data analysis software, thus saving time and resources associated with the data entry process

However, response rates can be low and the structure/interface/choice of technology may be off-putting or difficult to understand by some (Ilieva, Baron & Healey, 2002). An online survey platform was used to facilitate as wide of an outreach as possible, with the understanding that some may not have access to it or be aware of it, which may have affected the number of responses. This should be understood as one of the limitations of the results gathered through this analysis.

Interviews were conducted with interdisciplinary researchers to explore the details of their experiences learning GIS. As interviews are interactive, interviewers can press for complete, clear answers and can probe into any emerging topics (Alshenqeeti, 2014). This can broaden the scope of understanding investigated phenomena in a more naturalistic and less structured way (Alshenqeeti, 2014). Interviews that are recorded also offer the benefit that they can be reviewed several times by the researcher (when necessary) to help produce an accurate interview report (Berg, 2007). Interviews are not without their drawbacks, though; it is also argued that both the interviewer and the interviewee may have incomplete knowledge or even faulty memory (Alshenqeeti, 2014). Hammersley and Gomm (2008) also note that researchers should remember that:

> "… what people say in an interview will indeed be shaped, to some degree, by the questions they are asked; the conventions about what can be spoken about… by what time they think the interviewer wants; by what they believe he/she would approve or disapprove of." (p. 498).

To mitigate for the first weakness, multiple approaches were employed for this research, as discussed in this chapter and the next. The researcher initially piloted the interview with a small group to test the proposed structure, ensuring leading phrases and biased questions were avoided as much as possible. Due to the nature of a semi-structured interview, though, this could not be entirely pre-planned and some of what was said may have influenced interviewees. As such, this should also be considered a caveat of this research method.

Learning Diaries were employed with interdisciplinary learners actively learning GIS to investigate the learning process as it was happening. As stated by Richardson and Maltby (1995), “The exercise of diary writing is seen to promote both the qualities required for reflection i.e. open-mindedness and motivation, and also the skills, i.e. self-awareness, description and observation, critical analysis and problem solving, synthesis and evaluation.” (p. 235). Diaries could help to record details that may later be forgotten, not only about the material to be learned, but about the learning journey as well. As noted by Connor-Greene (2000), learning diaries also offer the teacher valuable insights into the student’s actual learning processes and help to diagnose possible misunderstandings. With that said, though, as learners may be aware that someone will be assessing their diary, they may censor themselves in some part to write in a way they believe the person reviewing would want them to write and that they may not be fully conscious of that (Nevalainen, Mantyranta & Pitkala, 2009). Furthermore, learners may not necessarily provide accurate descriptions of their learning strategies (Chamot, 2004). Learners were told that their diaries were not part of their graded assignments and were asked to be completely honest in their feedback – even if it was negative. They were also given instructions on what was being requested that they record when they began keeping their diary. However, it must be accepted that they may have misunderstood, not known particular terminology or still avoided writing certain descriptions down, which may have affected what was recorded and the subsequent results of this analysis.

With these research approaches outlined, this chapter will begin by investigating the following research questions, as illustrated in Figure 1.3:

- What challenges do people face in interdisciplinary research and how is it suggested that they solve those issues?
- Which GIS concepts are relevant to people in IDR?
- What are some of the learning approaches people involved in IDR have used to learn GIS?

These are considered with respect to the IDR challenges and suggested solutions (2.1 The Current State of Interdisciplinary Research) as well as GIS concepts, framed in particular by the Geographic Information Science and Technology (GIS&T) Body of Knowledge (BoK) (2.4.5 Geographic Information Science and Technology Body of Knowledge). As mentioned earlier, the two methods employed in this chapter to explore the posed questions were a methodical, large-scale analysis of articles published on IDR using GIS (4.1 Google Scholar Analysis) and an online survey to be answered by those with GIS and IDR experience (4.2 Online Survey). The Google Scholar Analysis was conducted by way of systematically searching for the most cited articles from top journals, based on metrics compiled by Google, which used GIS as part of the IDR undertaken. The online survey was constructed and then advertised through a variety of means (e.g. at conferences, via social media, mailing lists, etc.) to find out from those who engaged in IDR that used GIS about how they used it, issues they faced and how they overcame them.

Through these analyses, the answers to the research questions may begin to shed light on an overall understanding of GIS in IDR; these may then lead to further, more detailed, paths of inquiry, as patterns and trends begin to emerge.

4.1 Google Scholar Analysis[3]

4.1.1 Introduction

An important part of academic research is to share project outcomes so that those who are interested may build on them. Findings are often shared through published articles in various discipline or domain specific journals; however, unless the journal is within the researcher's area of interest, they may not be aware of the existence of associated articles that might be relevant. Google Scholar is a search engine designed and run by Google Inc. to specifically search academic books and articles and is a valuable tool for researchers in discovering such resources. Other scholarly search engines exist, such as Web of Science; however, studies have shown that Google Scholar continues to expand, covering most of the available literature data, which includes disciplines that might not be comprehensively covered by other search engines (de Winter, Zadpoor & Dodou, 2014). Bearing this in mind, the work that was undertaken therefore used Google Scholar.

To keep track of the prominence of publication sources, Google Scholar keeps and compiles metrics for journals, namely as the h5-index, which is defined as the 5-year median of the h-index, or the largest number h such that at least h articles in that publication were cited at least h times each (Google Inc., 2014). Each journal stored in Google's database will belong to one or more categories, as defined by Google; the 8 main categories are as follows:

[3] Extracts from this section were originally published, and have since been updated, in Rickles, P. & Ellul, C.E. (2014a). "Identifying important geographic information system concepts in interdisciplinary research: An analysis of Google Scholar." Paper presented at GIS Research UK, Glasgow, UK.

- Life Sciences & Earth sciences
- Business, Economics & Management
- Chemical & Material Sciences
- Engineering & Computer Science
- Humanities, Literature & Arts
- Health & Medical sciences
- Physics & Mathematics
- Social Sciences

These are then divided into 321 subcategories; however, some subcategories exist in multiple categories (e.g. the subcategory Architecture is listed in both Engineering & Computer Science as well as Social Sciences). Removing overlapping subcategories, there are a unique set of 277 subcategories; these will simply be referred to as categories from this point onwards. Journals are listed within these and ranked to identify, usually, the top 20 journals, by h5-index, for each category; however, it may be less than 20 if fewer journals exist in the category if it is a niche area.

This thus provides an ideal tool to identify prominent research where GIS has been used in an IDR context.

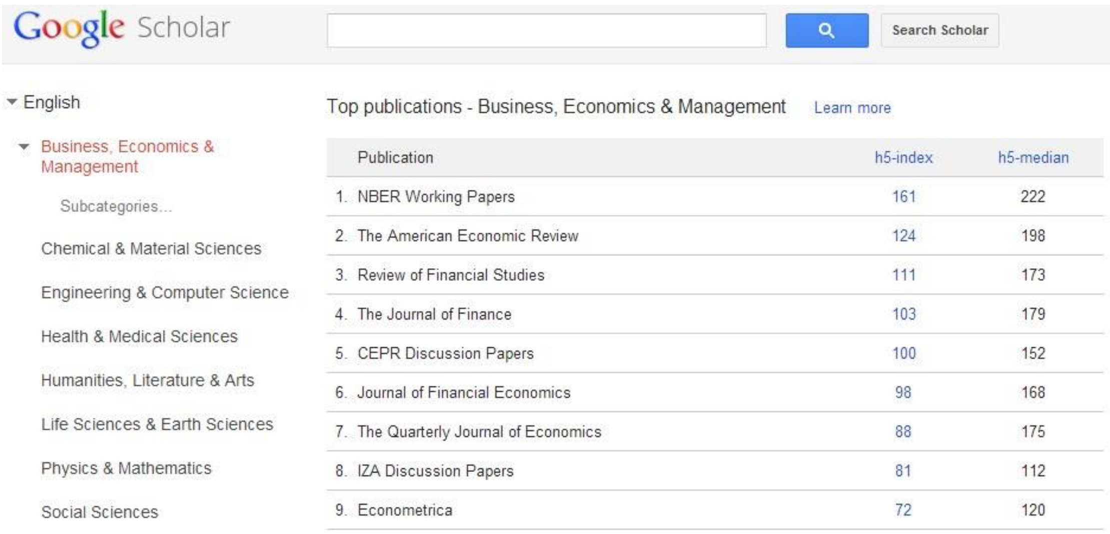
4.1.2 Methodology

To identify the relevant publications, a search process was conducted in 2013 to trawl all the top journals listed for all categories in Google Scholar's metrics, to search by journal, by category, for the first page of results returned and total number of search results returned when searching for "Geographic Information System", "Geographic Information Systems", "GIS", "Geographical Information System" and "Geographical Information Systems" - commonly used variations for GIS - AND "interdisciplinary", "multidisciplinary" or "transdisciplinary". It should be worth noting that the term "Geographic Information Science" was not included in this search, due to interest in the use of GIS as a tool rather than in reference to the discipline. Bearing this in mind, the result of this analysis was a list of the top cited articles from the top journals that self-identify as interdisciplinary, multidisciplinary, or transdisciplinary and use GIS.

It was determined that this process would need to be performed programmatically, given the number of searches that would need to be completed and the potential volume of data that may be collected. As an estimate, a search would be performed for each of the top 20 journals from each of the 277 categories and would need to be repeated for each of the variations of GIS. This would result in a possible 27,700 searches needing to be performed and, with 10 results displayed on the first page from the search, 277,000 results that would need to be catalogued. Therefore, custom PHP scripts were created and hosted on a web server to perform the steps outlined in the following sections (with code in A.1.2 Google Scholar Data Mining Code).

4.1.3 Methodology - Gathering Journal Information

Google Scholar's metrics page (shown in Figure 4.1) was accessed for each of the 277 categories (in English), which are listed in A.1.1 Google Metrics Categories.



	Publication	h5-index	h5-median
1.	NBER Working Papers	161	222
2.	The American Economic Review	124	198
3.	Review of Financial Studies	111	173
4.	The Journal of Finance	103	179
5.	CEPR Discussion Papers	100	152
6.	Journal of Financial Economics	98	168
7.	The Quarterly Journal of Economics	88	175
8.	IZA Discussion Papers	81	112
9.	Econometrica	72	120

Figure 4.1 *Example of Google Scholar's Metrics Page (Google Inc., 2014)*

This was carried out to record the ID for each category used in the metrics page's URL. For example, http://scholar.google.co.uk/citations?view_op=top_venues&hl=en&vq=bus is the URL for the Google Scholar metrics page for the Business, Economics & Management category, which shows the top 20 journals in that category, so the ID "bus" was recorded. The script google_scholar_miner_populate_journals.php (included in A.1.2.1 google_scholar_miner_populate_journals.php) was then run, which used the metrics page URL without the ID as a base (e.g. http://scholar.google.co.uk/citations?view_op=top_venues&hl=en&vq=) and looped through an array of the stored category IDs to programmatically access their metrics pages. Within that same code block, the HTML element ID for the table in each of the metrics pages that holds the journal information was used to access the following info on each of the top 20 journals listed under that category, which was written to a MySQL database table:

- category/subcategory name
- journal rank
- journal title

- journal h5 index
- journal h5 median

A column was also created in the table for each of the variations of GIS that was to be searched for that would be populated by google_scholar_miner_populate_articles.php.

4.1.4 Methodology - Generating Links and Downloading Web Pages

For each journal identified in the previous section, an advanced Google Scholar search was to be performed for the exact phrase using a variation of GIS, “interdisciplinary” or “multidisciplinary” or “transdisciplinary” and the articles published in the journal. An example of this search can be seen in Figure 4.2, using the exact phrase “Geographic Information System” that is looking for articles published in “Nature” that also have the word “interdisciplinary” or “multidisciplinary” or “transdisciplinary” in them.

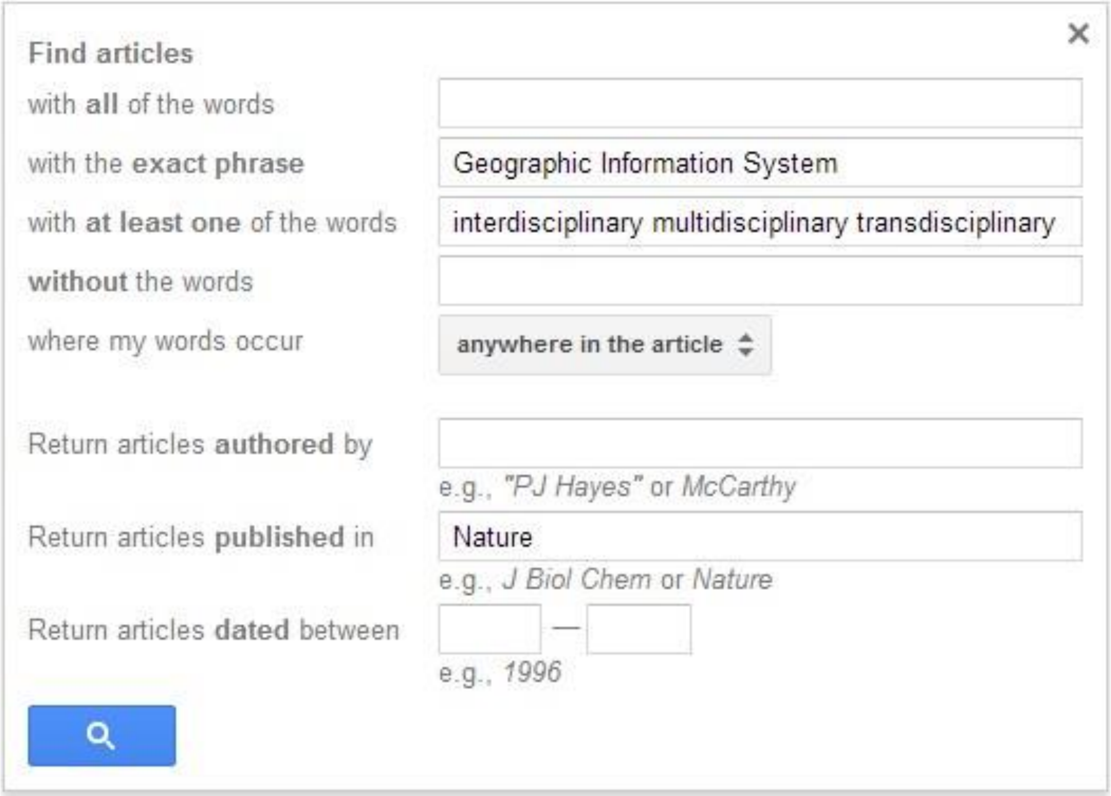


Figure 4.2 Example of Advanced Google Search Parameters

This search was to be performed programmatically; however, through testing, it was found that using the script to access the information from all of the searches online was getting blocked by Google Scholar. Therefore, an intermediary step was included, which used the script google_scholar_miner_generate_links.php (included in A.1.2.2 google_scholar_miner_generate_links.php) to generate a web page that would have links for all of the searches that would be performed. Next a Mozilla Firefox plugin called

DownloadThemAll! was used, which allowed the webpage of any/all URLs on a page to be locally saved. This was then run on a computer, which would download as many pages as possible before eventually getting temporarily blocked from doing so by Google Scholar, after which processing would be halted. The downloaded pages were then uploaded to the web server for reference by this script. Another computer would then be used to access this script; however, the links that would be generated would not include any of the pages that were already downloaded. This process was then repeated on a number of computers until all pages for all search combinations were downloaded.

4.1.5 Methodology - Extracting Information from Downloaded Web Pages

With the pages downloaded, information from the search results could then be extracted with another script titled google_scholar_miner_populate_articles.php (included in A.1.2.3 google_scholar_miner_populate_articles.php).

Using the example search that was given for Figure 4.2, Figure 4.3 shows the returned search result.

Figure 4.3 Example of the Returned Search from the Advanced Google Scholar Search

From this, the information that needed to be extracted became clear, and so the ID for the HTML elements from each search result were recorded to be used by the code to extract the necessary information (e.g. elements with the ID “gs_rt” on the page held the search result article title). This included all the necessary element IDs to record the total number of results returned from the search, as well as all the results’ information (e.g. article title, authors, etc.) from the first page only. Studies have shown that people often choose the first few results on the top of the search result list and ignore the rest (Guan

& Cutrell, 2007; Joachims et al, 2017), so it was deemed acceptable to only record the results from the first page. The citation count for each result was of particular interest, as this can act as an indicator of the recognised prominence of the work given that other studies are referencing its outputs.

google_scholar_miner_populate_articles.php began by creating a table for the variation of GIS that was currently being searched for and scraped the following information from each of the search results listed in the downloaded pages:

- category/subcategory name
- journal rank
- journal title
- journal h5 index
- journal h5 median
- article title
- article authors
- article year
- article URL
- article text returned by the search
- article citation count

The number of results from each search page was recorded for each journal in the table created by google_scholar_miner_populate_journals.php.

4.1.6 Methodology - Identifying the Top Categories and Cited Articles

The processes detailed using each of these scripts was then repeated for each variation of GIS to collect information on search results and articles that might have used any of those terms. With all the information recorded and collated by the original Google Scholar metrics' category, it was then possible to derive the top 10 categories by total search results for all journals listed as part of the category. This was repeated for all selected derivations of GIS ("Geographic Information System", "Geographic Information Systems", "GIS", "Geographical Information System" and "Geographical Information Systems"). Then, sorting by the total number of search results returned by term, using the top 10 categories, articles within these were sorted by "Cited by" count. The top cited articles from these categories were then reviewed to ensure that GIS did not have a mistaken meaning (e.g. Gastro-Intestinal System) and that both it and the term inter/multi/trans-disciplinary were actually used in the study, rather than part of the references, captions, etc. Should the top cited one not meet that criteria, the next most cited article was reviewed. This process was continued until an article was found in the category that met the criteria or until the remaining articles' cite count was less than 10. Though articles cited by 10 or less papers may have findings relevant to this work, it would be difficult to consider these articles to be "highly cited". In that case, the next top category by search results would be selected and the review would continue. This process has been illustrated in Figure 4.4.

To note, the top 10 categories and their selected top cited article were selected because of the top-ten effect, which is defined as the tendency for people to create round-number-category boundaries to interpret long ranked lists (Isaac & Schindler, 2014). This is said to make categorised information more cognitively accessible (Isaac & Schindler, 2014). As this complex analysis had collected a large number of results, with particular interest in the articles' citation count, and was to be delivered for a conference, only the top cited article from each of the top 10 categories were reviewed to keep analytical outputs simple for presentation and discussion purposes.

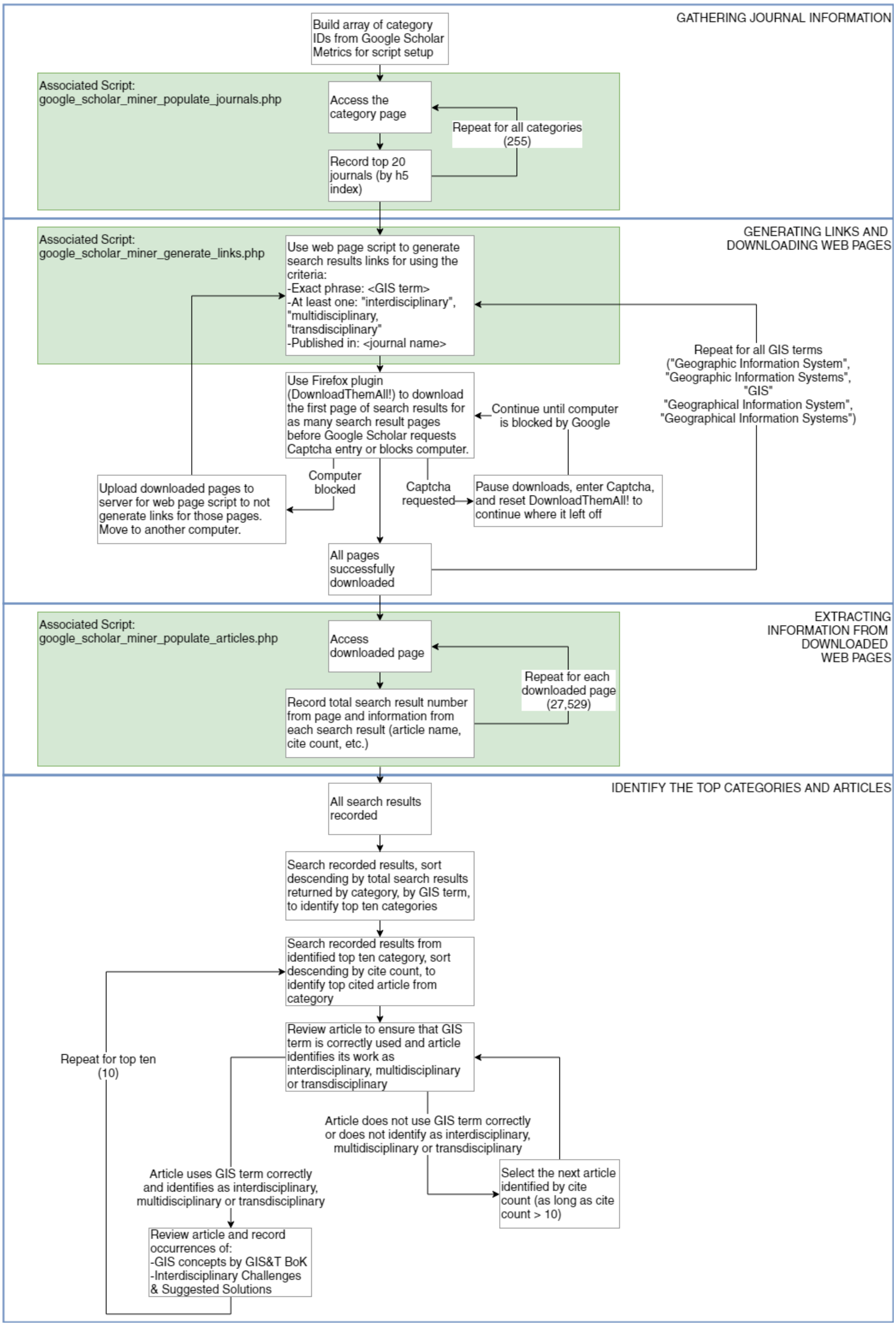


Figure 4.4 Google Scholar Analysis Process Diagram

4.1.7 Results

As calculated in 4.1.2 Methodology, 277,000 was the estimated maximum for the number of results that might be collected; however, not every category had 20 journals listed in their top 20. The following categories had less than 20 top journals listed:

- Circadian Rhythms & Sleep (13)
- Cryogenics & Refrigeration (14)
- Microscopy (14)
- Real-time & Embedded Systems (16)
- Economic History (17)
- Obesity (17)
- Emergency Management (18)
- Lipids (18)

Furthermore, not every journal search result returned a full page of 10 search results.

In total, 5,507 journals were searched, which across the variations of GIS resulted in a total of 27,535 searches. The total search results collected and number of results on the first page from the search results for each of the variations of GIS searched for from all recorded journals across all categories that also had “interdisciplinary” or “multidisciplinary” or “transdisciplinary” is detailed in Table 4.1.

Table 4.1 Results for number of journals searched, total search results and number of results on first page from Google Scholar Analysis

Variation of GIS	Total Search Results	Number of Results on First Page
Geographic Information System	8,678	3,755
Geographic Information Systems	11,089	4,374
GIS	29,726	2,200
Geographical Information System	5,909	2,823
Geographical Information Systems	6,754	8,694
	62,156	21,846

From what can be seen, “GIS” was the most commonly used variation of the term for GIS and the categories from this term had the top 10 counts by search result in comparison to the other terms. The categories were then sorted in descending order by their search results, to identify the top ten ones, and then the top cited article from each of those categories was reviewed to ensure that it actually used GIS and that the study identified itself as being interdisciplinary, multidisciplinary or transdisciplinary. Should the article not match that criteria the next one would be reviewed until the cite count was less than 10; at that point, the next category would be selected.

Review of the articles consisted of carefully reading them to pick out language that might describe a GIS concept, interdisciplinary issue or a suggested solution to one. Sentences were then highlighted and categorised by GIS&T BoK KA (introduced in 2.4.5 Geographic Information Science and Technology Body of Knowledge and selected as the curriculum to frame GIS concepts in 2.4.7 A Comparison of the Curricula in an IDR Context), one of the 8 IDR challenges or one of the 8 IDR suggested solutions (2.1 The Current State of Interdisciplinary Research). For example, the text “Conflicting Objectives” could correspond to the challenge “Personality Conflicts”, “Strong focus on education” could match “Provide Training on Technical and Supplemental Skills” and “Focus on database management” may signify GIS&T BoK KA “Design Aspects”. Figure 4.5 is an example of this categorisation work from one of the articles reviewed[4].

[4] Scans of the annotated articles can be found on the included USB drive, as detailed in A.1.4 Reviewed Articles.

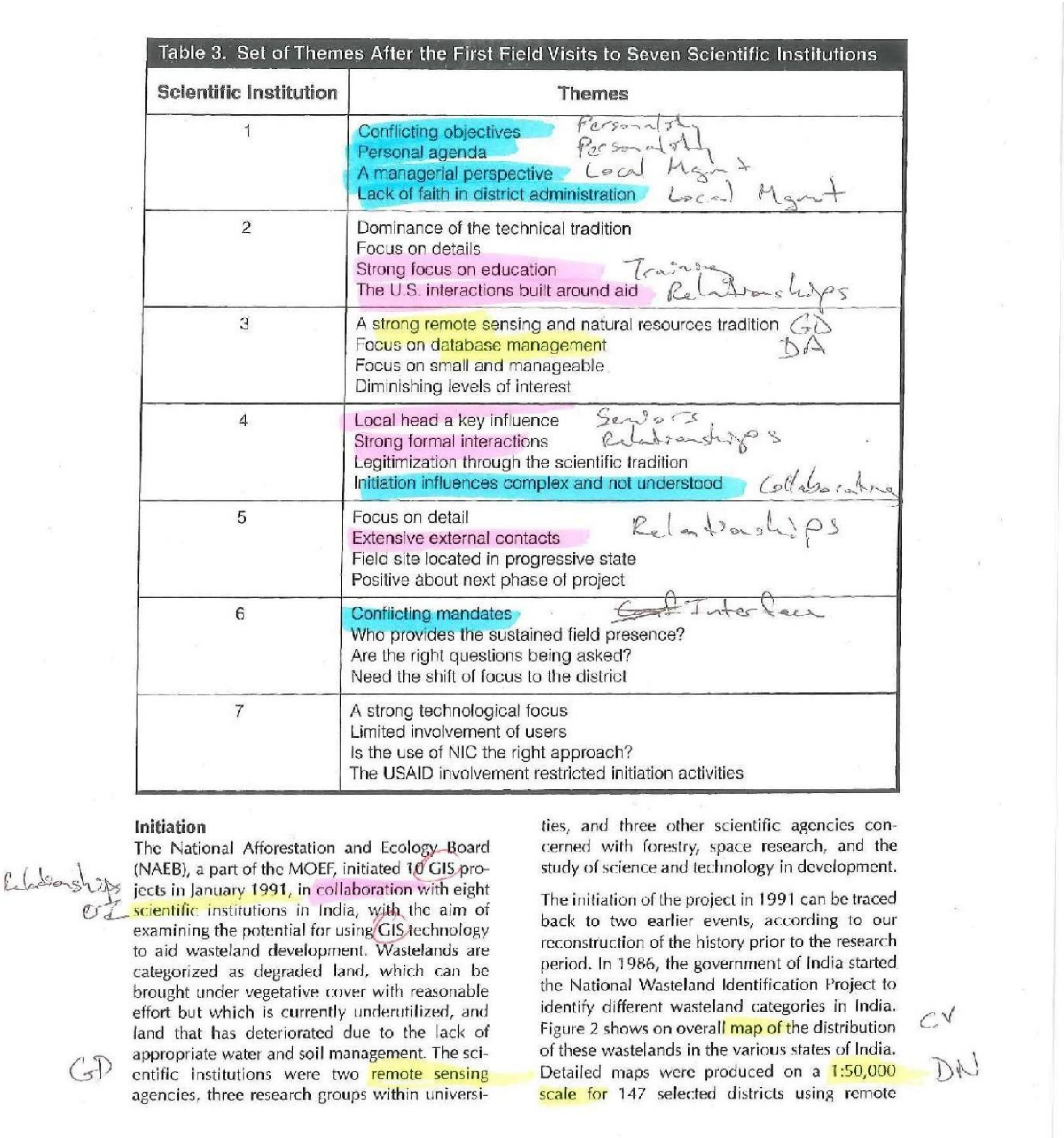


Table 3. Set of Themes After the First Field Visits to Seven Scientific Institutions	
Scientific Institution	**Themes**
1	Conflicting objectives Personal agenda A managerial perspective Lack of faith in district administration
2	Dominance of the technical tradition Focus on details Strong focus on education The U.S. interactions built around aid
3	A strong remote sensing and natural resources tradition Focus on database management Focus on small and manageable Diminishing levels of interest
4	Local head a key influence Strong formal interactions Legitimization through the scientific tradition Initiation influences complex and not understood
5	Focus on detail Extensive external contacts Field site located in progressive state Positive about next phase of project
6	Conflicting mandates Who provides the sustained field presence? Are the right questions being asked? Need the shift of focus to the district
7	A strong technological focus Limited involvement of users Is the use of NIC the right approach? The USAID involvement restricted initiation activities

Initiation

The National Afforestation and Ecology Board (NAEB), a part of the MOEF, initiated 10 GIS projects in January 1991, in collaboration with eight scientific institutions in India, with the aim of examining the potential for using GIS technology to aid wasteland development. Wastelands are categorized as degraded land, which can be brought under vegetative cover with reasonable effort but which is currently underutilized, and land that has deteriorated due to the lack of appropriate water and soil management. The scientific institutions were two remote sensing agencies, three research groups within universities, and three other scientific agencies concerned with forestry, space research, and the study of science and technology in development.

The initiation of the project in 1991 can be traced back to two earlier events, according to our reconstruction of the history prior to the research period. In 1986, the government of India started the National Wasteland Identification Project to identify different wasteland categories in India. Figure 2 shows on overall map of the distribution of these wastelands in the various states of India. Detailed maps were produced on a 1:50,000 scale for 147 selected districts using remote

Figure 4.5 Annotated article, categorising terms by GIS&T BoK KA, one of the 8 IDR challenges or suggested solutions

Articles were reviewed using the method described to select the top ten; the tables with details on this process are in A.1.3 SQL Export and Key Tables and the articles selected from this review, using those from the search variation for “GIS”, as this was the most commonly used term, have been compiled in Table 4.2.

Table 4.2 Top *Cited Articles from Google Scholar Categories with the Most Search Results (Searching "GIS" and "inter/multi/trans-disciplinary")*

Category	Number of Search Results Returned for Category	Top Cited Article from Category	Cited by Count	Result Rank from Search Result Page	Journal	h5 index	Category / Subcategory Rank (top 20)
Ecology	1730	"The influence of catchment land use of stream integrity across multiple spatial scales" (Allan, Erickson & Fay, 1997)	650	2	Freshwater Biology	43	12
Remote Sensing	1484	"GIS-Based Habitat Modeling Using Logistic Multiple Regression - A Study of the Mt. Graham Red Squirrel" (Pereira & Itami, 1991)	337	1	Photogrammetric Engineering and Remote Sensing	25	8
Sustainable Development	1240	"Energy and Environmental Aspects of Using Corn Stover for Fuel Ethanol" (Sheehan et al., 2003)	392	1	Journal of Industrial Ecology	31	11
Geography & Cartography	1131	"GIS-based multicriteria decision analysis: a survey of the literature" (Malczewski, 2006)	350	2	International Journal of Geographical Information Science	35	3
Environmental & Occupational Medicine	1059	"Using Geographic Information Systems for Exposure Assessment in Environmental Epidemiology Studies" (Nuckols, Ward & Jarup, 2004)	190	1	Environmental Health Perspectives	82	1
Environmental Sciences	890	"Applications of GIS to the Modeling of NonPoint Source Pollutants in the Vadose Zone: A Conference Overview" (Corwin & Wagenet, 1996)	86	1	Journal of Environmental Quality	40	19

Epidemiology	848	"Towards evidence-based, GIS-driven national spatial health information infrastructure and surveillance services in the United Kingdom" (Boulos, 2004)	103	3	International Journal of Health Geographics	32	18
Urban Studies & Planning	814	"Impervious Surface Coverage: The Emergence of a Key Environmental Indicator" (Arnold Jr. & Gibbons, 1996)	1098	9	Journal of the American Planning Association	27	11
Geology	763	"The Database of Individual Seismogenic Sources (DISS), version 3: Summarizing 20 years of research on Italy's earthquake geology" (Basili et al., 2008)	176	2	Tectonophysics	41	7
Engineering & Computer Science (general)	727	"GIS for District-Level Administration in India: Problems and Opportunities" (Walsham & Sahay, 1999)	487	1	Management Information Systems Quarterly	68	8

Analysis of these results has shown that the top cited article, meeting these search criteria in the identified categories, is “Impervious Surface Coverage: The Emergence of a Key Environmental Indicator” (Arnold Jr. & Gibbons, 1996), from the “Urban Studies & Planning” category, which was cited 1098 times. In contrast, though, “Ecology” projects seem to more prominently use GIS, as this category has returned the most search results (1730). It is also worth noting that 9 of the 10 top cited articles are within the first 5 search results returned on the page. Conversely, though, there does not appear to be a correlation between the top cited articles being in the top ranked journal by category.

With regard to articles mentioning IDR common challenges and suggested solutions as well as GIS concepts, their occurrence across the 10 articles reviewed were recorded and are summarised in Table 4.3, Table 4.4 and Table 4.5.

Table 4.3 Common Challenges and the Number of Top Articles that Mention Them

Common Challenges	No. Articles
Difficulties Related to Collaborating with Other Disciplines	5
Problems Being at the Interface Between Disciplines	4
Intransigence from Current Institutional Structures	3
Lack of Local Level Management	3
Time Constraints	2
Personality Conflicts	2
Licencing and Ownership	1
Lack of Opportunities for People	0

Table 4.4 Suggested Solutions and the Number of Top Articles that Mention Them

Suggested Solutions	No. Articles
Build Relationships with Members of the Group	7
Provide Training on Technical and Supplemental Skills	5
Incorporate Effective Management Practices to Construct Clear Objectives and Evaluation	4
Increase Funding Opportunities and Adapt Existing Ones for IDR	3
Incentivise IDR with Support and Rewards	3
Include Senior Staff and Interested Parties	2
Establish an Institutional Structure that Prioritises IDR	1
Discourage Disciplinary “Selfishness”	1

Table 4.5 GIS&T BoK Knowledge Areas and Number of Top Articles that Mention Their Concepts

GIS&T BoK Knowledge Area	No. Articles
Geospatial Data	10
Analytical Methods	10
Data Modeling	9
Cartography and Visualisation	9
Conceptual Foundations	9
GIS&T and Society	6
Data Manipulation	6
Geocomputation	5
Organizational and Institutional Aspects	3
Design Aspects	3

From these results, it can be seen that “Difficulties Related to Collaborating with Other Disciplines” is the most common challenge for all of these studies, “Build Relationships with Members of the Group” is often suggested as the solution and that “Geospatial Data” and “Analytical Methods” are the most important Knowledge Areas. It is also worth noting that 8 of the 10 articles had maps, which shows these studies’ interest to use maps to visualise results. Spatially processed data were also taken into other programs for statistical analyses, as the tables and charts derived from these seemed to also be desired outputs.

4.1.8 Discussion

This work represents a preliminary investigation to pull together a list of published studies, from top journals, as compiled by Google Scholar to find interdisciplinary research projects that used GIS. This novel approach was taken to facilitate the collection of a large amount of data in order to better understand who was publishing in which areas and how many other researchers may be citing that work and building on it. Google Scholar’s Advanced Search did not provide the ability to search for articles and sort by cite count, so this method was devised. The approach taken can be considered screen scraping, which is a process that uses scripts to parse HTML sources in order to extract data (Stein, 2002). This allowed programmatic collection of information that would have been difficult and time consuming to manually do. The data collected helped to provide a comprehensive overview and to inform on directions for further investigation in order to extrapolate information from prominent articles that may be relevant.

This process, though, was not without its recognised issues. Screen scraping has been said to be brittle; if the HTML page structure is changed, the process will stop working (Stein, 2002). As this work was completed in 2013, it is questionable as to whether these scripts would work today. Regardless, even at that time, between pages, sometimes, the article details would not be recorded correctly, possibly due to misalignment of HTML element IDs. A number of occurrences were noted where, upon manual verification of the saved search result page, the cite count did not match the article title recorded in the database, though it did for another article on the page. There were also concerns around the Google Scholar categories and the assignment of journals to them. With regard to the categories, it is unclear how or why some have been created. For example, “Biology” seems sensible as a category, given that it is a recognised discipline; however, “Ceramic Engineering” seems quite niche and without further explanation on the category creation process, it is not clear how or why a topic becomes one. It may also be questionable as to whether a journal belongs in one category or another. Furthermore, there were cases where journals were listed in multiple categories, which has resulted in duplicated search results in the database.

Some of the categorisation process used as part of this piece of analysis may also warrant discussion. The criteria of ensuring articles correctly used GIS and self-identified as inter/multi/trans-disciplinary may also be questionable. Some articles reviewed that were not selected had used maps, but did not explicitly use the term GIS within it. Similarly, some reviewed could likely be considered inter/multi/trans-disciplinary projects, but as they did not self-identify as such within the body of the article, they were also not selected. The selected articles were reviewed and text was categorised as indicating a GIS&T BoK KA concept, IDR challenge or suggested solution. Some may agree with some of the categorisation decisions that were made of the text; however, others may have been interpreted differently by another researcher. Nevertheless, these decisions were made to establish a verifiable process for others to understand how the results were reached and all associated data have been included in A.1.4 Reviewed Articles for the sake of transparency.

The results from Google Scholar itself also had issues. “GIS” was the variation of GIS that returned the most results; however, this also included different acronyms (e.g. Gastro-Intestinal System) and parts of words (e.g. biolo<u>gis</u>t), even though an exact term search was used. Furthermore, some search results returned did not include either GIS or inter/multi/trans-disciplinary, so it is unclear as to why Google Scholar had included these in the result. In respect to the results that are presented to the user, it is known that Google as a search engine uses a users' search data to refine its search algorithms, presenting them with individualised search results (Haucap & Heimeshoff, 2014). Bearing this in mind, as multiple computers were used as part of the data collection process, the computers' search results would have been slightly different, which may have affected the study. These algorithms are also continually evolving, and so if this process were to be rerun today, the results may be different.

Nevertheless, these results provide some insight and initial understanding of which interdisciplinary challenges, proposed solutions and GIS concepts may be relevant in practice. The congruence between these findings and the literature review for the most common challenge ("Difficulties Related to Collaborating with Other Disciplines") identifies where further efforts should be made to address issues before they arise; however, the proposed solutions differ. Though studies may believe that "Building Relationships with Members of the Group" is a more viable solution than "Providing Training on Technical and Supplemental Skills", it could mean that there is a missed opportunity for solving problems in a better way. Perhaps combining both through group learning activities may lead to a more holistic and sustainable solution.

Beyond IDR understandings, though, by reviewing how GIS was used and applied in these projects, it can be seen that Geospatial Data and Analytical Methods come through as the most prominent KAs. GIS was most often used for the digitisation or creation of information, incorporation of satellite or aerial imagery and investigations into data quality of existing sources. Analyses of created or collected data were also important for the compilation and reporting of associated statistics. Though 8 of the 10 articles contained maps, further tables and charts that were included also showed that the final output of spatially processed data is not necessarily just a map. The interplay between quantitative and qualitative data across disciplines with maps show that GIS can be used at different points in analyses. Whether it was to identify the regionality of features to then statistically analyse them or to take collected data and show them spatially, GIS can be a useful tool for analysis and visualisation in IDR projects. Bearing this in mind, the output of this work begins to convey an understanding of how prominent studies using interdisciplinary approaches have used GIS and which concepts may be worth focussing on for supporting resources.

4.2 Online Survey[5]

4.2.1 Introduction

An online survey was utilised to further explore how interdisciplinary researchers learned to use and apply GIS. This survey was developed and then piloted with a small group to refine it for deployment. The final version is available in A.2.1 Survey Questions. Questions were asked on which GIS concepts were important to researchers' work, GIS software packages that they used and how researchers sought out information on tasks they needed to do with a GIS.

4.2.2 Methodology

The online survey was used to collect information about those who have been involved in interdisciplinary research and how they have learned to use and apply GIS in their work. The survey was constructed in Opinio, UCL's approved survey administration platform, to securely store collected information in compliance with the 1998 UK Data Protection Act and approved UCL ethics procedures[6]. Respondents were notified that completion and submission of the survey was recognised as their acknowledgement and approval of the contribution of their data. No personal data were stored, outside of respondents' email addresses, only if they were happy to be contacted with any further follow up questions, if necessary.

The survey consisted of nine questions with an estimated time of completion of ten minutes. Questions asked in the survey were focused around the following areas:

- Which GIS platforms have participants used?
- How did participants obtain information on GIS concepts?
- Which GIS concepts were important to participants?

To construct these questions, some research was required to select the options to include. Identified GIS platforms for the survey included first ArcGIS (2016) (including desktop, server and online versions) and QGIS (2016), the top two platforms used in the GIS industry (Mapping Out the GIS Software Landscape 2016). Google Earth (2016), Google Maps (2016), MapInfo (2016) and Manifold (2016) were also included as these

[5] Extracts from this section as well as 5.1 One-on-One Interviews have been published in Rickles, P., Ellul, C.E. & Haklay, M. (2017). "A suggested framework and guidelines for learning GIS in Interdisciplinary Research." Geo:Geography and Environment, 4(2), 1-18.

[6] In accordance with UCL ethics procedures in place at the time of the survey, no formal ethical approval was required for this work as it was research involving the use of non-sensitive, completely anonymous educational tests, survey and interview procedures. The participants were not defined as "vulnerable" and participation would not induce undue psychological stress or anxiety.

are also commonly used platforms (Hinks 2013; Best GIS Software 2016). Questions on the platforms asked about participants' level of experience with them, whether it was none, some, moderate or (almost) daily experience. A blank "Other" field was also included for participants to list a platform that might not have been one of the given options.

For questions on how information was gathered, commonly used ones were suggested which included an internet search, watching a video, following a tutorial, using a software help manual, asking a more experienced person, or posting on a forum. Efficacy of the methods was also explored as participants could select whether each of the options were very effective, effective, not very effective or not applicable based on their experiences around gathering information for learning GIS. A blank "Other" field was also included for participants to list any information gathering option that might not have been included.

Finally, for simplicity, GIS concepts inquired about were at the GIS&T BoK KA level, rather than unit or topic level. Participants were asked in the survey about the KAs, by being presented a descriptive statement of them (Table 4.6), and asked about their relevance to participants' undertaken GIS work (extremely relevant, very relevant, relevant, somewhat relevant, not relevant).

Table 4.6 Descriptions used to represent GIS&T BoK KAs utilised as part of the online survey

GIS&T BoK KA	Survey Description
Analytical Methods	I have queried and analysed geospatial data in a GIS
Cartography and Visualisation	I have designed and created maps in a GIS
Conceptual Foundations	I have questioned the spatial relationships or philosophical perspectives of GIS data
Data Manipulation	I have used a GIS to prepare maps at different scales or convert map data from one format to another
Data Modeling	I have structured and managed data in a GIS database
Design Aspects	I have planned the system design and deployment of a GIS
Geocomputation	I have created algorithms or modelling processes which take into account uncertainty inside a GIS
Geospatial Data	I have created new data inside of a GIS and/or used satellite imagery inside of a GIS
GIS&T and Society	I have had to be concerned about the legal aspects or ethics of the data in a GIS
Organizational and Institutional Aspects	I have formatted GIS data in a way that improves its usability by others

With the survey constructed, approved and launched, a link to it was shared through professional networks via email, Twitter and advertising at conferences, such as the GIS Research UK conference, the Royal Geographical Society with IBG Annual Conference and Esri UK User Conference, from August 2014 until August 2015. Once completed, responses were reviewed by tabulating and reclassifying information, as necessary. Although it was planned, in the case of sufficient number of responses, to carry out a quantitative analysis of survey results, eventually only 45 responses were collected and therefore a more qualitative approach was taken. This approach was used to identify patterns in the data through reviewing charts and statistics from the data and comparing those with information respondents gave in the final, open-ended question. Any responses to the open-ended question that might provide new avenues of inquiry were also taken into consideration. The outputs of this work will be shared in the following section and have also been published in Rickles, Ellul & Haklay (2017).

4.2.3 Results

Of the 45 responses gathered, respondents identified their disciplinary backgrounds from 17 unique disciplines, which included Geographic Information Science [6], Geography (Physical and Human) [4], Remote Sensing [3], Computer Science and Software Engineering [2], Forestry [2], Cartography [1], Ecology [1], Education [1], General Humanities [1], History [1], Librarianship [1], Marine Biology [1], Music [1], Oceanography [1], Petroleum Engineering [1], Psychology [1] and Urban and Rural Planning [1] (16 respondents did not identify their discipline).

Results show that respondents were most experienced with ArcGIS, Google Earth and Google Maps; less so with QGIS and MapInfo; only 4 respondents had experience with Manifold; and only 3 respondents had used gvSIG (2016) (Figure 4.6). Other GIS platforms that were named in an open text “Other” field that was provided were GeoMedia (2016) [2 respondents], GRASS GIS (2016), Neatline (2016), MapWindow GIS (2016), Terra Amazon (2016), ERDAS IMAGINE (2016), PostGIS (2016), CartoDB (now CARTO) (2016), GeoServer (2016) and MiraMon Map Reader (2016); however, these were not included as part of Figure 4.6, as there were not a significant number of respondents that identified them (less than 5%).

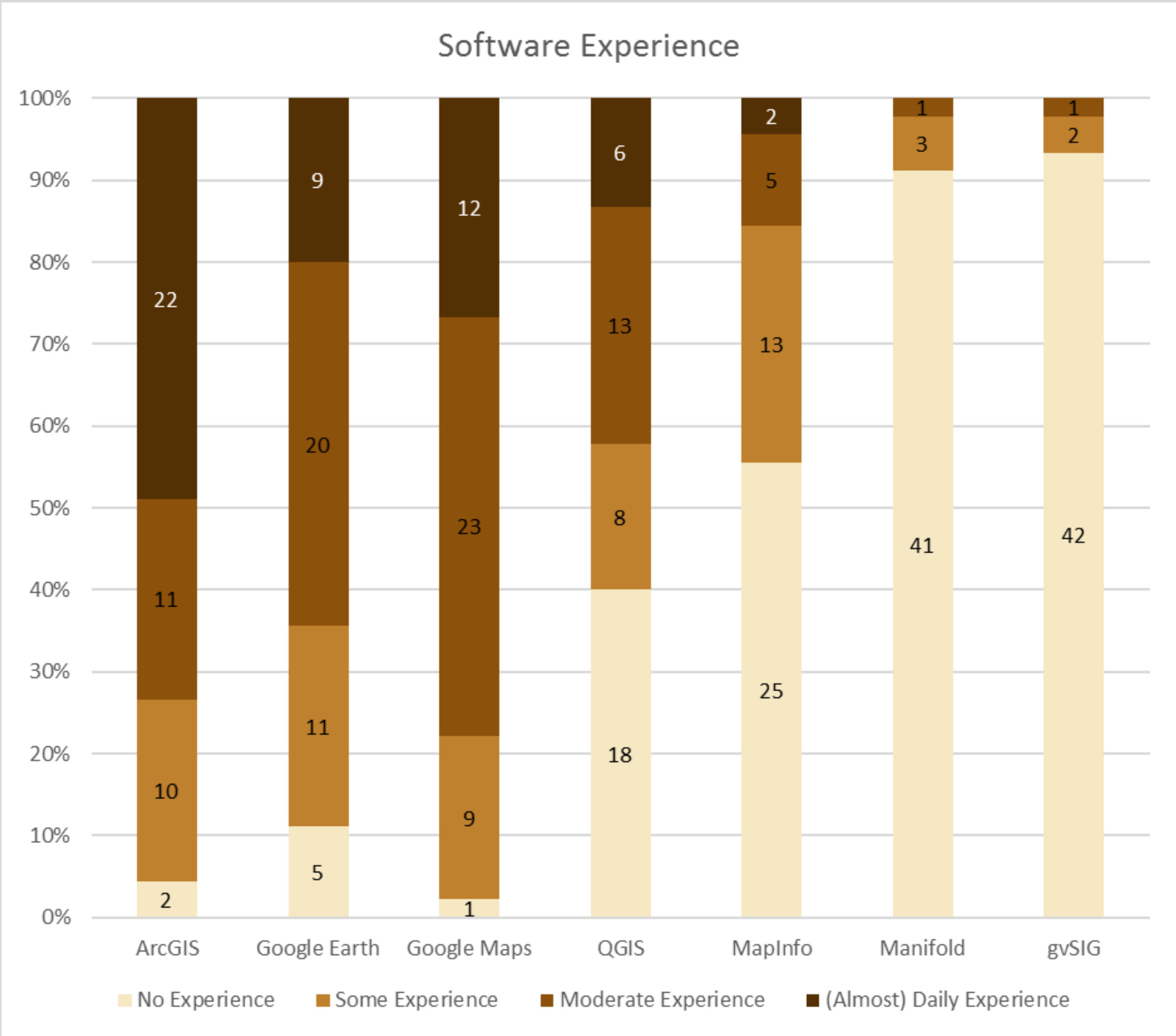


Figure 4.6 Online Survey Results – GIS Platforms Used [45 responses]

Figure 4.7 highlights that all respondents felt that an internet search was effective and many felt watch a video (89%), ask a more experienced person (87%) and follow a tutorial (87%) were also effective; however, in comparison, only 48% of them considered posting on a forum to be effective.

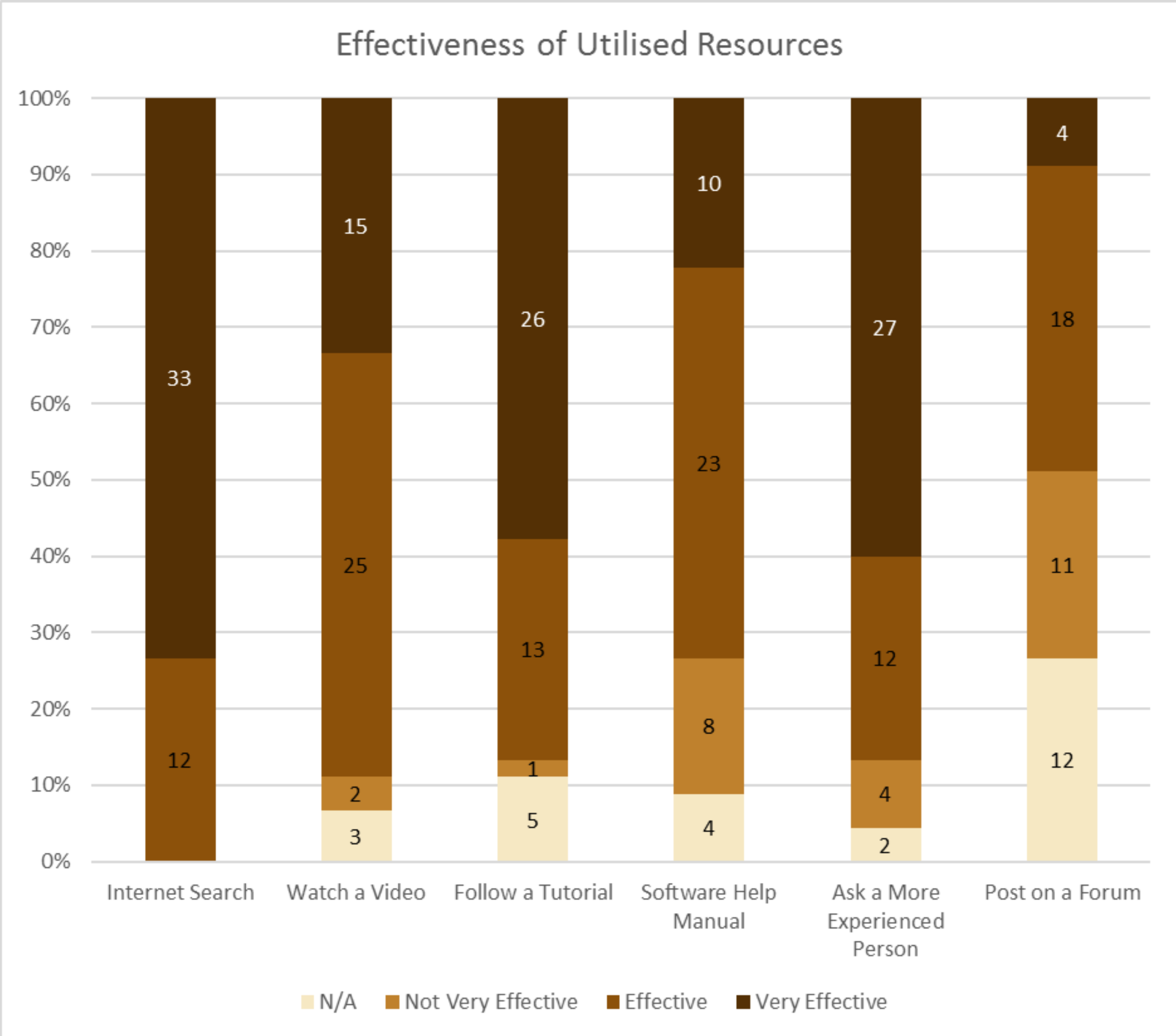


Figure 4.7 Online Survey Results – Methods for Obtaining Information [45 responses]

From Figure 4.8, it can be seen that concepts from Analytical Methods and Cartography and Visualisation were felt to be relevant to 43 of the 45 respondents (96%) and 42 respondents (93%) respectively. Data Manipulation was considered relevant by 41 respondents (91%), then Conceptual Foundations by 40 respondents (89%). Data Modeling and Geospatial Data were both considered relevant by 39 respondents (87%). Organizational and Institutional Aspects, GIS&T and Society, Geocomputation and Design Aspects concepts were considered relevant by 36 respondents (80%), 32 respondents (71%), 30 respondents (67%) and 27 respondents (60%) respectively. It is also worth noting that all the KAs were considered relevant by more than half of respondents.

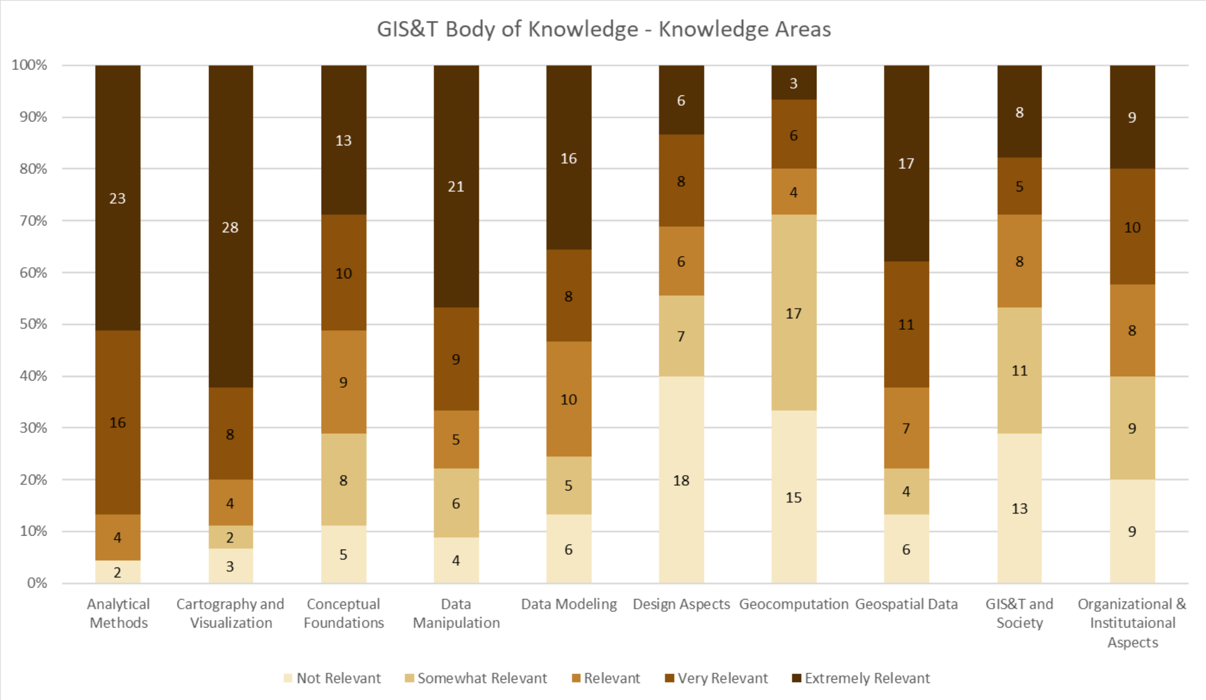


Figure 4.8 Online Survey Results – Importance of GIS&T BoK KAs [45 responses]

The survey concluded with an open text question where respondents could add any other comments they wished. One respondent stated that a Massive Online Open Course (MOOC) was effective method of learning for them and another suggested the inclusion of GIS in more higher education curricula. When searching for answers via an internet search, 15 respondents said that they would mention the GIS platform in their search and many used specialist terms as part of it (e.g. “buffer”, “cluster”, “raster”, etc.). One respondent was keen for continued use of GIS and further opportunities to use it in IDR; however, another noted that those from different disciplines may not know how to properly apply GIS or understand how it could positively contribute to their analyses.

> *“Many people in other disciplines (not geography or GIS etc.) often think of GIS* (GISystems) as just a software package or tools, without recognizing or understanding GIScience. They are not critical of the methods and often do not really know what they want to actually find out - just that they have this data and someone in GIS can use it for them. They also don't often realise that simply plotting points or a few layers for a simple map is pretty easy and could be done *by almost anyone.”*

4.2.4 Discussion

Overall, responses from the online survey suggest that there are a variety of disciplines using GIS as part of interdisciplinary research and that they are using multiple platforms as part of their work, though there appears to be a preference for ArcGIS and Google platforms. This may be in part due to the prevalence of these software packages at the researchers’ institutions or perhaps that these technologies have an existing user base and a number of published resources for help that are available online. Corresponding with that, internet searches, watching videos or asking a more experienced person for help did seem to be preferred methods for seeking information on GIS tasks. These may provide immediate assistance to GIS users, whereas other methods might not. For example, software help manuals may use unfamiliar terms or acronyms that could be difficult to understand (Jeong et al., 2009). Similarly, posting a question on a relevant online forum may not receive a response in what the user may consider to be a timely fashion. GIS&T BoK KAs perceived to be most relevant were Analytical Methods and Cartography and Visualization, though Data Manipulation, Geospatial Data, Data Modeling and Conceptual Foundations were only slightly less relevant. Perhaps because of some confusion or ambiguity over the language used for the KAs, there may have been some misunderstandings; however, it may be implied from this that data, their analyses, the resulting maps for informed decision making and what it all may mean play a role in the reasons why IDR projects use GIS.

The results of the survey, though, highlight certain issues associated with gathering data of this kind. As “Time Constraints” is a recognised issue for interdisciplinary researchers, the survey had to be short and concise to improve the potential number of respondents. Crawford, Couper and Lamias (2001) stated that, amongst other factors that affect the perceived burden of completing an online survey, when respondents were told that a survey would take a shorter amount of time, they were more likely to accept a survey invitation and complete it. Bearing this in mind, this was why the survey was only 9 questions that could be completed in 10 minutes. It would have been desirable to also explore IDR challenges and suggested solutions; however, these questions were cut from the final survey to reduce the time it would take to complete the survey. It was also decided to administer the survey online, in comparison to a paper questionnaire, as online administration allowed for responses to be given when convenient for respondents through an easily accessible platform. This medium, however, meant that the survey could only facilitate further exploration of some of the questions in a limited fashion – in the way of open text questions – and respondents could only be followed up with if they gave their permission to be contacted later.

Further to the survey medium issues, the variety of the identified disciplines of respondents, of those that answered the question on disciplinary background, may seem to show a bias towards Geography or Geography related disciplines, in which the use of GIS may not be surprising. This could be attributed to the networks that the survey was advertised on – namely at Geography related conferences and through Geography related contacts. This is because these people are part of the professional network of the researcher, the researcher's supervisors and colleagues who research and work in the area of Geography. In order to have a wider reach of disciplines, the survey could have been advertised through central University resources or perhaps with help from colleagues in disciplines further away from Geography. However, this is a recognised barrier in interdisciplinary research, as identifying participants outside of one's network to establish communications and contacts is problematic (Augsburg & Henry, 2009). Regardless, this does not invalidate the results of the survey, but it should be noted in respect to the outputs.

The use of language in the survey as well as its mention in the outputs are worth further investigation. Indeed the words used in the titles of the GIS&T BoK KAs include some that are specific GIS terms (e.g. Geocomputation, Cartography and Visualization), which may be confusing to those coming from disciplines that may be unfamiliar with GIS, or words that may be too vague and easily misunderstood (e.g. Design Aspects, Analytical Methods, Conceptual Foundations). Therefore, if that is the case with some of the respondents to the survey, the perceived relevance of some of the KAs may be inaccurate due to confusion on which topics they encompass. This may not necessarily be the case, though; descriptions were included that attempted to minimise on disciplinary jargon and explain KAs using simplified language, which may have helped respondents understand what the KAs stood for. Furthermore, as noted in the answers from some of the respondents, when searching for information, they would often mention the GIS package used – this, along with fact that the survey was advertised through Geography or Geography related professional networks, may indicate that respondents were familiar enough with GIS to understand the language used.

4.3 Google Scholar Analysis and Online Survey – Summary of Findings

The combined understandings of 4.1 Google Scholar Analysis and 4.2 Online Survey begin to provide some understanding to the research questions stated at the beginning of this chapter. Both methods show a wide range of disciplines currently using GIS in IDR – this therefore highlights the importance of understanding issues with GIS in IDR, as they may affect a wide audience of researchers. It also verifies that such projects have been and continue to be undertaken outside of the localised examples described in Chapter 3. From the outputs of the Google Scholar Analysis, with respect to the IDR challenges and suggested solutions (2.1 The Current State of Interdisciplinary Research), "Difficulties Related to Collaborating with Other Disciplines", or the knowledge gap, is a common challenge and "Building Relationships with Members of the Group" or "Provide Training on Technical and Supplemental Skills" are often suggested as solutions. Focusing on bridging the knowledge gap through training, resources may be constructed, in this respect about GIS, that both the Google Scholar Analysis and online survey outputs suggest should be on GIS&T BoK KAs such as Geospatial Data, Analytical Methods and Cartography and Visualization. The relevance of these KAs is understandable; if a GIS is defined as a system able to capture, store, analyse, manage and present data that are linked to geographical locations (Bhat, Shah & Ahmad, 2011), then the concepts of those identified KAs are core to GIS itself. In respect to learning these concepts, the survey results show how those in IDR have gone about doing so; these informal methods, such as an internet search, watching a video, asking a more experienced person or following a tutorial seem to be preferred learning methods. Interest in tutorials complements the IDR solution of "Provide Training on Technical and Supplemental Skills". Therefore, not only are tutorials for learning GIS a suggested option, they appear to be a preferred one amongst others. By aligning those materials so they teach topics from Geospatial Data, Analytical Methods and Cartography and Visualization, interdisciplinary researchers may be better supported in learning what they want to learn through a medium they actively utilise.

The results from the Google Scholar Analysis and the online survey can not only help to refine further avenues of inquiry, but also what those methods' shortcomings may have been and what other complementary methods of data collection and analysis may be used. This work has added evidence to what the relevant IDR challenges, suggested solutions, GIS concepts and methods of information seeking are; however, further work is necessary to investigate the details of why they may be relevant. Interviews with those who have learned and applied GIS in IDR (5.1 One-on-One Interviews) and the review of diaries that were kept by those who were actively going through the process of learning GIS (5.2 Learning Diaries) were two further methods that were used in this research. These are explained in greater detail in the next chapter and help bridge the gap between the identification and the practice of learning relevant concepts to use and apply GIS in IDR.

Chapter 5 - The Praxes of Learning GIS in IDR

Different perspectives on issues may provide different ways of understanding breadth and depth of issues. The previous chapter described research to obtain an overview of the issues that affected those learning Geographic Information Systems (GIS) in interdisciplinary research (IDR). Building on the IDR challenges and suggested solutions from 2.1 The Current State of Interdisciplinary Research, the results from 4.1 Google Scholar Analysis and 4.2 Online Survey suggested that the most common challenge, not just in theory, but in practice, is “Difficulties Related to Collaborating with Other Disciplines”, also referred to as the knowledge gap. Similarly, “Building Relationships with Members of the Group” and “Provide Training on Technical and Supplemental Skills” were suggested as well as employed as solutions based on those research outputs. Furthermore, Geospatial Data, Analytical Methods and Cartography and Visualization were identified as the Geographic Information Science & Technology (GIS&T) Body of Knowledge (BoK) Knowledge Areas (KAs) that have common topics utilised in IDR.

The survey also gave a preliminary insight into how interdisciplinary researchers have gone about learning GIS. Often using ArcGIS, QGIS and web GIS platforms, interdisciplinary researchers have largely learned informally through internet searches, watching videos, following a tutorial or asking a more experienced person (4.2.3 Results). Informal learning, though initially discussed and linked to other approaches associated with adult learning in 2.2 Educational Approaches, may not be the most efficient or effective approach of learning GIS.

Knowing now what interdisciplinary researchers wish to learn about GIS and that people do seek training to address their gap in knowledge, this chapter further researches associated topics to answer the following questions, which is also illustrated in Figure 1.3:

- What challenges do people face in interdisciplinary research and how is it suggested that they solve those issues?
- Which GIS concepts are relevant to people in IDR?
- What are some of the learning approaches people involved in IDR have used to learn GIS?

For an in-depth exploration of these issues, one-on-one Interviews were conducted (5.1 One-on-One Interviews) and Learning Diaries kept by interdisciplinary researchers actively learning GIS were reviewed (5.2 Learning Diaries). The interviews, through following a structure, allowed for topics that may arise to immediately be inquired about with interviewees, should there be potential new avenues of insight into the research questions. The learning diaries also enable reporting on current experiences and facilitate reflection for the learner, which may improve uptake of GIS concepts and understanding.

5.1 One-on-One Interviews

5.1.1 Introduction

The one-on-one interviews were conducted to explore topics in a more detailed way than the Survey and Google Scholar Analysis. To begin, it was necessary to understand the interview process itself. There are a number of different types of interviews; Patton (1990) suggests three in particular: the informal conversational interview, the general interview guide approach and the standardized open-ended interview. The informal conversational interview, also described as “unstructured interviewing”, is an interview where most questions asked to the interviewee will flow from immediate conversation, directed in part by observations made by the interviewer. The opposite to this approach is the standardized open-ended interview, in which full wording of each question is defined before the interview and questions must be asked in the same way to ensure interviewees receive the same stimuli to ensure comparability of their answers. These approaches have strengths as well as weaknesses. The informal conversational interview allows for spontaneous changes in direction of the interview as determined by the interviewer, which may lead to findings previously not envisaged as outcomes by the interview; however, its lack of structure makes repeatability rather difficult – one interview may yield extremely useful results while others may not provide anything particularly usable by the study. The standardized open-ended interview, by having a structure, ensures that each interview provides answers on and around the topics to be investigated; however, it provides little in the way of exploring any new issues that may arise. This may mean that, after processing the results from this type of interview, a new vein of questions may need to be constructed and new interviews held; however, the original participants may no longer be available and the immediate opportunity in the original interviews was lost.

Combining the strengths of both of these types of interviews, though, is the interview guide approach. This approach allows the compilation of lists of questions and issues for the interview in advance, yet allows the interviewer to explore, probe and ask questions to build a conversation within a particular subject area; this may also be described as a semi-structured interview (Cohen & Crabtree, 2006). It was determined that a semi-structured interview would be delivered, to ensure questions were aligned to gather information in a uniform fashion on major aspects of this research (e.g. interdisciplinary challenges/suggested solutions, GIS&T BoK KAs, information gathering techniques, software used), as it allowed for other topics to be touched upon as part of the interview that could be more deeply explored.

The resulting structure of combined questions and card sort activity were reviewed and piloted with a few volunteers and aspects of the interview were adjusted accordingly; the final questions and materials for the interviews may be seen in A.3.1 Interview Questions. Upon finalisation, people were initially identified who would be suitable, were then contacted and interviews were set up at a convenient date and time. The following sections detail that work and subsequent results.

5.1.2 Methodology

To gain a more in-depth understanding than is possible in a survey, interdisciplinary researchers who have already learned GIS for their work were asked to identify the GIS concepts that mattered to them. Similar to the survey (4.2.2 Methodology), the interview design was constructed to ensure that ethics procedures were met. The structure for the interviews would be set to ask questions that would investigate the following areas:

- Which GIS platforms have participants used?
- How did participants obtain information on GIS concepts?
- Which GIS concepts were important to participants?

Interviews began with interviewees being asked for their consent for the interview to be recorded and being notified that any recordings and derived data would be collected and securely stored in compliance with the 1998 UK Data Protection Act (in force at the time). With their consent, interviewees were then asked questions that centred on their initial (positive or negative) experiences with GIS, which GIS platforms they used as part of their interdisciplinary projects and how they obtained information on a task to do inside of a GIS when they did not know how to do something, including a recollection of what words they used as search terms. The GIS platforms that were inquired about were initially derived from those from the survey (4.2.2 Methodology), which included ArcGIS, QGIS, Google Earth, Google Maps, MapInfo and Manifold. Interviewees were also asked about the same search methods from the survey, which were an internet search, watching a video, following a tutorial, using a software help manual, asking a more experienced person, or posting on a forum. They were then asked if they felt those methods of searching for information were effective in helping them achieve their goals with GIS and if they would take a (face-to-face or online) course instead, if that were available to them.

After these initial questions, participants were asked to do a “card sort” activity. Interviewees were given a set of cards with key phrases on them that represented selected topics from KAs in the GIS&T BoK (as initially discussed in 2.4.5 Geographic Information Science and Technology Body of Knowledge) written on each card and asked to organise them by grouping related concepts into an order (Jahrami, Marnoch & Gray, 2009). As Jahrami, Marnoch and Gray (2009) state, “Cards, once sorted, can form the basis of concept maps where connecting phrases indicate why cards are organized in the manner that they are.” (p. 178). Interviewees’ choices for sorting the cards are neither right or wrong, but simply shows their perspective on the topics put forward by the cards. Bearing this in mind, an advantage of the card sort is that by avoiding direct questions, interviewees will share their real views with as little distortion as possible. (Jahrami, Marnoch & Gray, 2009). The participants were asked to arrange the cards, ranking them in respect to their importance to the researchers’ work. The KA title and the descriptions listed on the cards, which were topics from the KAs, are outlined in Table 5.1 and an example of arranged cards can be seen in Figure 5.1, recorded from one of the interviews.

Table 5.1 Card Descriptions using Topics from GIS&T BoK KAs utilised as part of the interview activity

GIS&T BoK KA	Card Description (Topics)
Analytical Methods	Attribute & Spatial Queries, Geometric Measures, Spatial & Network Analyses
Cartography and Visualization	Symbolization, Spatialization, Map Design & Production
Conceptual Foundations	Space & Time, Philosophical Perspectives, Spatial Relationships
Data Manipulation	Generalization, Interpolation, Transformations
Data Modeling	Database Management, Triangulated Irregular Networks (TINs), 3D Models
Design Aspects	Resource Planning, Database Design, User Interfaces
Geocomputation	Genetic Algorithms, Simulation Modeling, Fuzzy Sets
Geospatial Data	Georeferencing Systems & Map Projections, Digitizing, Global Positioning System (GPS) & Satellite Imagery
GIS&T and Society	Legal Aspects, Ethics, Property Rights
Organizational and Institutional Aspects	Systems Management, Staff Development & Training Opportunities, Spatial Data Infrastructures (SDIs) & Standardization

Figure 5.1 GIS&T BoK KA cards as arranged by an interviewee

It should be noted that the descriptions used on the cards differed from those offered in the survey due to the fact that the descriptions in the survey needed to be self-explanatory. The descriptions on the cards, however, could be inquired about in greater detail as part of the interview, should any of the topics not be understandable.

Again, as the interviews allowed topics to be more deeply investigated, interviewees were given a similar exercise using cards on interdisciplinary challenges and suggested solutions, as derived from earlier work (2.1 The Current State of Interdisciplinary Research). They were again asked to rank these cards, based upon which ones they believe to be the most or least important to interdisciplinary research, based on their experiences. The challenges and suggested solutions along with their descriptions were listed on the cards as described in Table 5.2 and Table 5.3 and examples of arranged cards can be seen in Figure 5.2 and Figure 5.3, recorded from one of the interviews.

Table 5.2 Card Descriptions for Interdisciplinary Challenges

Interdisciplinary Challenges	Card Description
Difficulties Related to Collaborating with Other Disciplines	Lack of familiarity of a new discipline's language and culture or vice versa
Personality Conflicts	The team doesn't function as optimally as it could do due to issues associated with collaborating
Time Constraints	Not enough time to meet disciplinary and interdisciplinary obligations
Intransigence from Current Institutional Structures	Connections between departments/universities do not facilitate transfer of funds/resources
Problems Being at the Interface Between Disciplines	Overlap of knowledge domains can result in methodological conflicts
Lack of Opportunities for People	Interdisciplinary work not considered as relevant as disciplinary work when seeking employment/funding
Licencing and Ownership Ambiguities	Difficulties ascertaining intellectual property rights for outputs of interdisciplinary work
Lack of Local Level Management	Unclear goals and direction due to ineffective/conflicting decisions at the project level

Table 5.3 Card Descriptions for Suggested Solutions to Interdisciplinary Challenges

Suggested Solutions to Interdisciplinary Challenges	Card Description
Provide Training on Technical and Supplemental Skills	Teach team members how to use the tools they are to use on the project
Build Relationships with Members of the Group	Fostering a collaborative environment through establishing positive understandings with team members
Include Senior Staff and Interested Parties	Bring in interdisciplinary mentors and research collaborators to work toward agreements on key issues
Incorporate Effective Management Practices to Construct Clear Objectives and Evaluation	Include benchmarks to ensure goals are being met
Increase Funding Opportunities and Adapt Existing Ones for Interdisciplinary Research	Provide seed corn money for networking and community activities
Incentivise Interdisciplinary Research with Support and Rewards	Provide job security for interdisciplinary staff and pay bonuses
Establish an Institutional Structure that Prioritises Interdisciplinary Research	Revise hiring practices and flexibility in resource sharing
Discourage "Disciplinary Selfishness"	No one discipline is more important than another and all involved on the project succeed or fail together

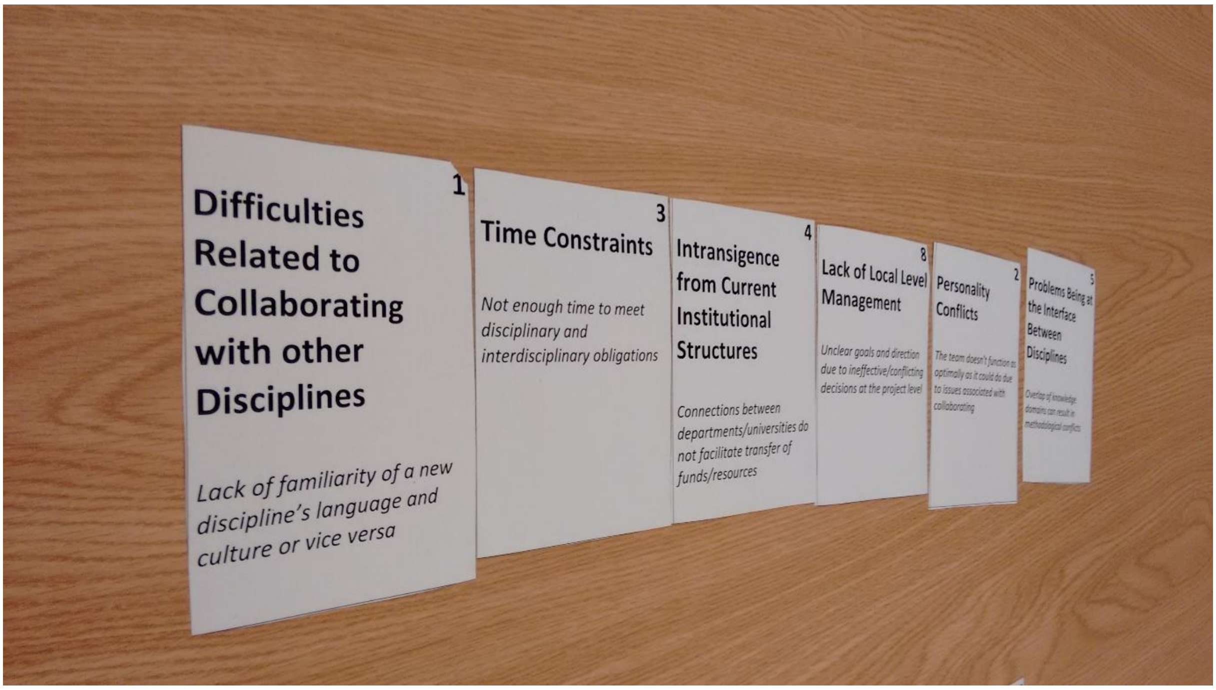


Figure 5.2 IDR Challenge cards as arranged by an interviewee

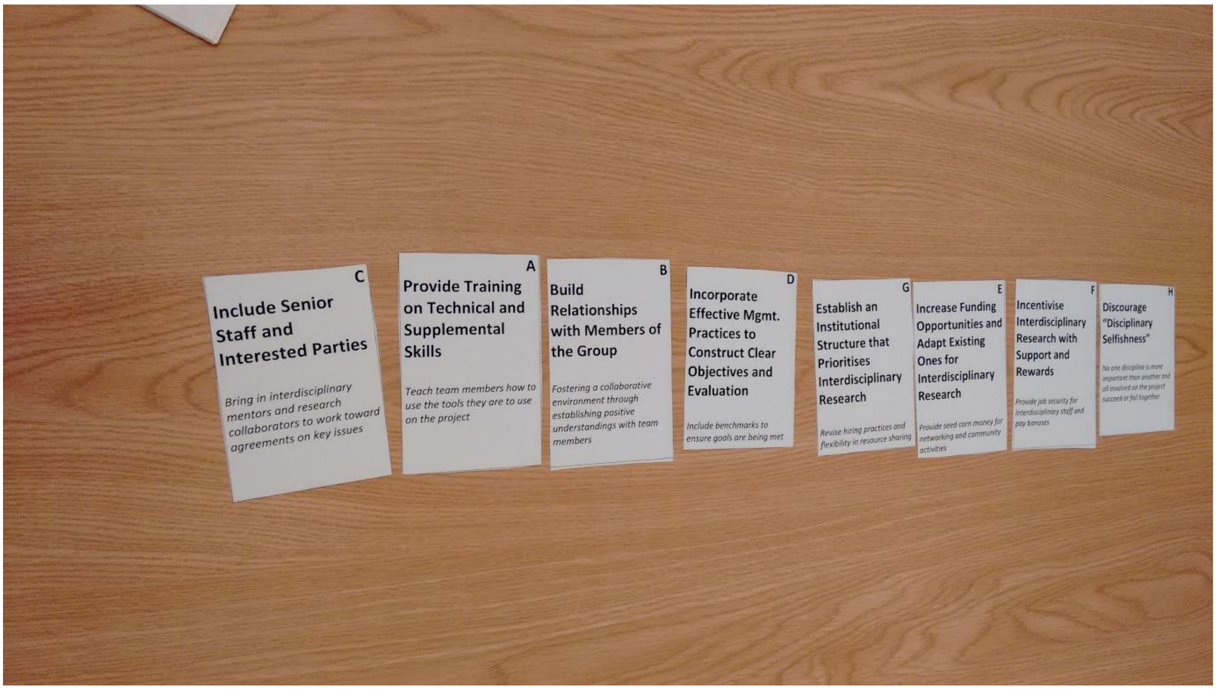


Figure 5.3 Suggested Solutions to IDR Challenges cards as arranged by an interviewee

From July 2014 to August 2015, 11 interviews were conducted using questions in a semi-structured qualitative interview format with individuals at various institutes that were contacted through professional networks. These people volunteered to share their experiences and their anonymised information is presented in Table 5.4.

Table 5.4 Background information and associated University of Interviewees

Interviewee	Background	Associated University
Participant A	PhD student in Anthropology	UCL
Participant B	Researcher with a background in Evolutionary Biology	UCL
Participant C	PhD student in Psychology	UCL
Participant D	PhD student in Anthropology	UCL
Participant E	Researcher with a background in Archaeology	UCL
Participant F	Researcher with a background in Architecture	UCL
Participant G	Researcher with a background in Marine Biology	University of California, Santa Barbara
Participant H	Lecturer in Psychology	University of California, Santa Barbara
Participant I	Researcher with a background in Library Sciences	University of California, Santa Barbara
Participant J	MSc student in Ecology	UCL
Participant K	MSc student in Molecular Biology	UCL

During the interviews, audio recordings of the interviews were made so they could be reviewed afterwards and any relevant points of interest would be transcribed. To record the results of the card arranging exercises, photos were taken. After the interviews, the interviewer made notes about any key points that may have emerged during the interview and transcribed the recordings. The results from these interviews, which will be discussed in the following section, were also published in Rickles, Ellul & Haklay (2017).

5.1.3 Results – Interview Questions

Focusing first on GIS platforms, it was found that interviewees predominantly used QGIS [7], ArcGIS [6], and web GIS platforms [6] (grouping together mentioned platforms - Google Maps [3], OpenStreetMap (2016) [2], GPSies (2016) [1], Sketchup (2016) [1] and bespoke ones [Community Maps (2016) [3], Wheelmap (2016) [1], SeaSketch (2016) [2]), as seen in Figure 5.4. Manifold and MapInfo, on the other hand, exhibited very little in the way of use and other GIS technologies mentioned were R (2016) and more generally GPS. Three interviewees commented on using specific platforms (QGIS and web GIS) because they were considered simple and user friendly.

“It's a lot easier to start with something like, say, Google Maps, which has got really simple tools, because I did find the Manifold interface quite difficult.” (Participant E)

*“… I found it [QGIS] a lot easier to use becau*se it was very basic, but also used ArcGIS with in-*depth, lengthy layer files as QGIS didn’t have the necessary processing power.”* (Participant D)

“QGIS seems more user friendly; all the buttons seem to make sense.” (Participant J)

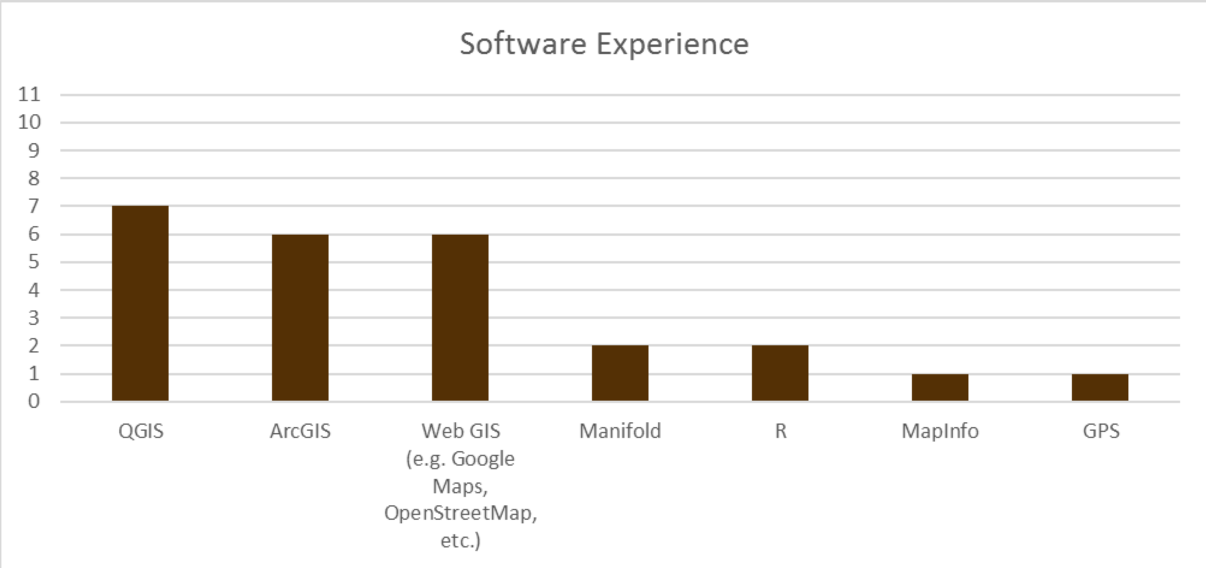


Figure 5.4 One-on-One Interview Results – GIS Platforms Used [11 interviews]

Figure 5.5 shows that interviewees, when searching for answers, mostly asked a more experienced person (91%), did an internet search (91%) or watched a video (73%). Other methods used include taking a short course (18%), reading a book (18%) or using social media (9%).

"You can just spend ages wandering around [with regard to internet searches for information] and not knowing what you're doing, and actually that can be very negative because then you can get frustrated and daunted and feel a bit of an idiot. Whereas if you just, say, ask somebody for help, then, you know, they can show you how to do something and it can be much more positive experience." (Participant E)

“I used YouTube a lot… I kind of like this process of ‘you click here’, you can see where the arrow is going on the screen, you can see what that person is doing, you can see the outputs of that, and t*hey’re talking you through it.”* (Participant A)

“[For internet searches] Always put in the software; the answer will come back using the software that you use and it’ll also be in layman’s terms so that I understand it.” (Participant D)

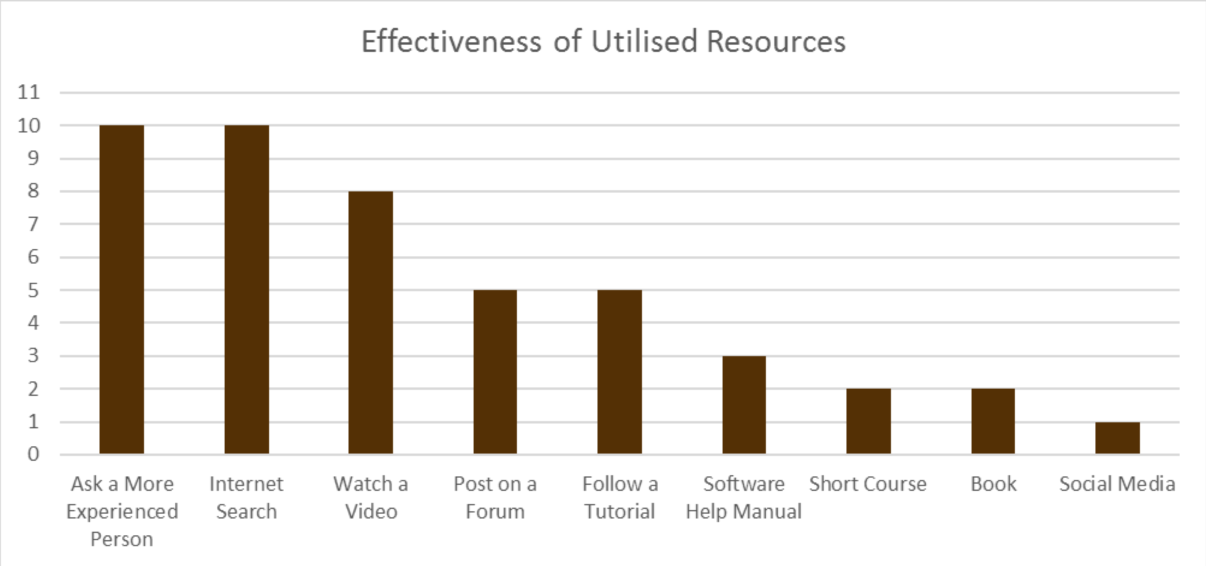


Figure 5.5 One-on-One Interview Results – Methods for Obtaining Information [11 interviews]

Given how people had sought out information for the tasks they had to do in the GIS, interviewees were also asked that, if a short course were available to teach them GIS, would that be something they would be interested in and, if so, would they prefer an online or face-to-face course. Almost all interviewees [10 out of 11] said they would take a course and of those who would almost all would have preferred a face-to-face course [9] as opposed to an online one [1]. The interviewee who would not have preferred the short course, though, did respond with the following:

> “I probably wouldn't have done a course, unless it [GIS work] was taking up a large proportion of what I needed to do. I just wouldn't have seen the relevance of doing a course.” (Participant B)

Building on that, interest in a short course, with the preference for a face-to-face one, did seem conditional to some [2] with regard to project limitations (e.g. time, cost, etc.). Comments in favour of face-to-face were as follows:

> "I hate online courses; it's just not my learning style. I need to interact with people." (Participant B)

> "When you're learning something from scratch, a person is so much better to teach you because they can bend and flex with your issues and your style of learning." (Participant D)

> "The good thing about face to face is that if you hit a problem, you can get it sorted out straight away." (Participant E)

> "You can ask people if you've got a question - you can just ask someone directly. I'd much prefer that." (Participant F)

The interviewee who did prefer online learning, though, did raise the following point in favour of online resources:

> "… through online learning, first of all, before the questions arise, having the material presented in such a way so that I can, say, pause the video and really kind of think carefully about what was just said before being presented with additional material is just crucial. You can't pause an instructor, but you can pause a video. That's just really important for me in terms of learning." (Participant G)

Overall, the following comment by an interviewee acts as testament to one of the benefits of undertaking some form of training or learning prior to working with GIS:

> "I think if I knew the basics of GIS, that I can use 'this' to do 'this', I could've planned out my project a bit better." (Participant J)

5.1.4 Results – Interview Card Activity

After the initial questions, interviewees were then presented a series of cards that were representative of the GIS&T BoK KAs, IDR Challenges and IDR Suggested Solutions as individual card sorting activities to investigate their understanding and perceived relevance of the outlined topics. Interviewees were presented with the cards, given a short description of them and then asked to arrange the cards in a way that would rank the topics on them from most to least relevant, setting aside any cards with topics they felt were not relevant to their experiences in interdisciplinary research. Examples of card arrangements for the topics can be seen in Figure 5.1, Figure 5.2 and Figure 5.3, as were recorded during the interviews.

Figure 5.6 shows a stacked bar graph summarising the perceived relevance of the GIS&T BoK KAs from the card sorting activity performed by the interviewees. It can be seen from this that, when asked about the GIS&T BoK KAs, interviewees felt Cartography and Visualization was the most relevant, as some ranked it as the #1 most relevant KA [4], most ranked it as #2 [6] and only one [1] interviewee ranked it a bit lower (#5). Geospatial Data was also perceived to be quite relevant, having been ranked #1-4 by almost all of the interviewees [9 out of 11]. Analytical Methods was also considered relevant by many, ranked #1 by some [2], #2 by others [3] and #3-5 by a few more [3]. Geocomputation and Organizational and Institutional Aspects were considered irrelevant to most interviewees [7], which may suggest that the topics in these KAs may be less relevant to interdisciplinary researchers. It is interesting to note, though, that with regard to Cartography and Visualization, not a single interviewee believed this KA to be irrelevant. As stated by one interviewee:

> *"I think that [Cartography and Visualisation] is really important because that's the power of the map."* (Participant E)

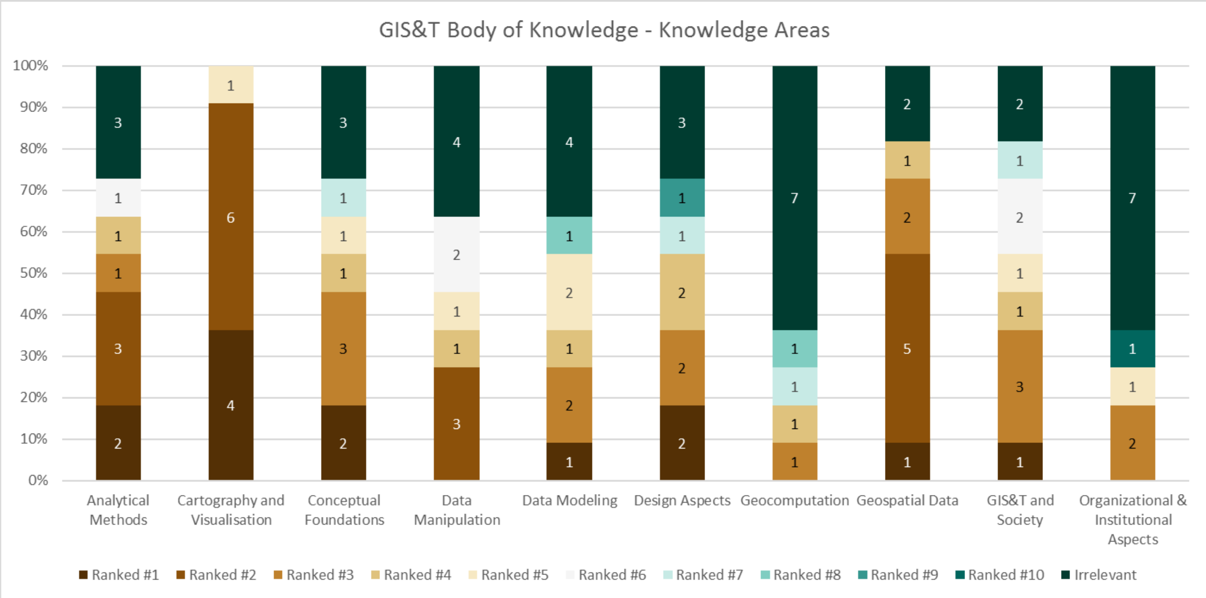


Figure 5.6 One-on-One Interview Results – Importance of GIS&T BoK KAs [11 interviews]

As interviews were semi-structured, other topics of interest on the GIS&T BoK KA were investigated as interviewees shared their thoughts. A noted issue that arose was around interviewees properly understanding the language used for the KAs and their topics, so even with descriptions on the cards and from the interviewer, perceptions of relevance may be slightly off. Indeed, the difficulty of understanding GIS / discipline specific language can be said to be one of the unforeseen findings from the interviews. In this respect, all interviewees had issues with the language used and, when asked about their perceptions on terms used around GIS and on the cards from this activity, they each had the following to say:

> *“… I find there’s a lot of this in GIS language, there’s a lot of bullshit, a lot of ‘I can’t be bothered to tell you what this language means’.”* (Participant A)
>
> “Language - what does that mean in your discipline vs. what does that mean in another discipline and understanding... That's frequently an issue.” (Participant B)
>
> "I do not even know what that means [Geocomputation]; it sounds very science-y." (Participant C)
>
> "I don't even know what some of these 'Geocomputations' mean! ... 'Fuzzy Sets' - what's that even mean? ... 'Triangulated Irregular Networks' - that's just hokum, abra kadabra voodoo, that is." (Participant D)
>
> “Words like 'Genetic Algorithm' make *me want to run away… I have no idea what that means! … ‘Geocomputation’ is a bit of a mouth*-full." (Participant E)
>
> "As a non-user prior to using it, you're kind of put off by the amount of technical bumpf and language around it that it would almost dissuade you almost, like put you off, you know?” (Participant F)
>
> "*’Fuzzy Sets’* - that's something I don't understand." (Participant G)

“Sometimes the same word means different things in different disciplines or it has different connotations... There's a lot of learning each other's terminology.” (Participant H)

“They [GIS&T BoK KAs] are all kind of jargon-y… Just slapping ‘Geo’ at the beginning of something doesn’t necessarily help anybody.” (Participant I)

“I don’t really understand a lot of them [words used]… A lot of it’s quite jargon-y.” (Participant J)

“It'd be nice to know what they all [specialist terms] mean.” (Participant K)

After the first card activity on the GIS&T BoK KAs, the cards were cleared away and the next set of cards were set out in front of the interviewee on IDR Challenges (initially identified in 2.1 The Current State of Interdisciplinary Research). After being presented with the cards and reviewing their descriptions, interviewees were again asked to sort cards with regard to perceived relevance of the challenges, based upon their experiences, and set those they considered to be irrelevant to the side. The results from this were compiled and are summarised in the stacked bar chart in Figure 5.7.

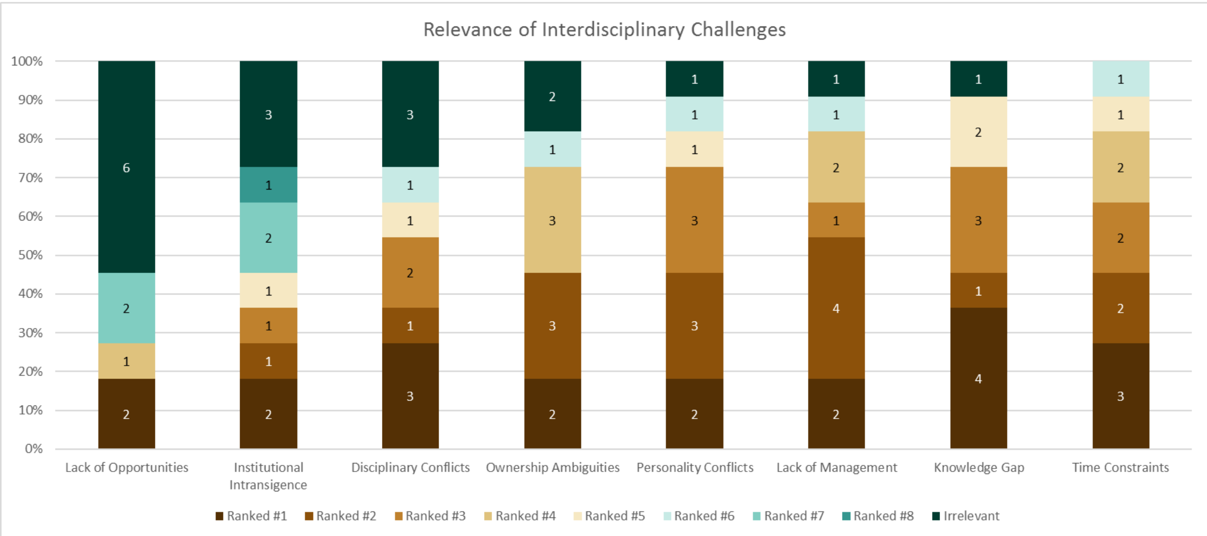


Figure 5.7 One-on-One Interview Results – Relevance of Interdisciplinary Challenges [11 interviews]

From the challenges, it can be seen that Time Constraints was considered a relevant issue, as interviewees ranked its relevance as #1 [3], #2 [2], #3 [2], #4 [2], #5 [1] and #6 [1] – none of the interviewees considered this challenge to be irrelevant. The Knowledge Gap, was also relevant, ranked by some as #1 [4], #2 [1], #3 [3] and #5 [2]. Personality Conflicts was considered about as relevant, being ranked as #1-3 [2, 3 and 3, respectively] and lower in the rankings (#5 and #6) by others [1 each]. Lack of Management was another issue considered important, as many ranked it #1-4 [2, 4, 1 and 2, respectively] and one [1] interviewee less so (#6). Some comments from interviewees worth noting with regard to these identified challenges are as follows:

> "I think there were some people who pushed their agendas more [than others]." (Participant A)
>
> "Time - not having enough time to understand the respective disciplines, concepts that they have and way in which they do things, talk, glossaries, thesaurus..." (Participant B)
>
> "Get someone properly managing the project; I think that would've been the number one thing. I think, get someone with more seniority. Someone either with seniority or just some sort of managerial experience or know how to check up on the project, tie everything back to the original project goals, make sure everyone's getting along fine, and everyone's doing what they're supposed to be doing and *they don't have any problems."* (Participant C)
>
> "Spend more time in the early stages of the project learning about the different methodologies from different disciplines, language, developing a glossary of terms and explanations so that people understand when they're talking about X this is what they mean." (Participant B)

More than half of the interviewees also considered Lack of Opportunities to be irrelevant [6]; therefore, though identified in literature, this may not be an issue many encounter – perhaps suggesting that many who have engaged in IDR feel there are opportunities for people with such a skillset. However, with regard to Lack of Opportunities, two [2] interviewees had the following to say:

> "The problem is that, in my home department... [they] have no recognition of this need [for interdisciplinary research] and to communicate the recognition of this need is very difficult... So in that sense, you're doing a lot of work for no recognition." (Participant A)
>
> "Because I worked across the two disciplines, I found myself falling down a bit of a hole in the middle, really. The people in Geography didn't really get what I did and the people in Archaeology didn't think I was an Archaeologist... To be honest, that's one of the reasons I got out of academia." (Participant E)

After discussing IDR Challenges, these cards were cleared away and the final set of cards were presented to interviewees on Suggested Solutions to IDR Challenges, again, as derived from the literature (2.1 The Current State of Interdisciplinary Research). These cards were then described and interviewees were asked to arrange the cards with regard to the most to least relevant suggested solutions, based upon their experience, and to set any solutions considered to be irrelevant to the side. Figure 5.8 is a stacked bar graph that summarises the outputs of this card activity's rankings.

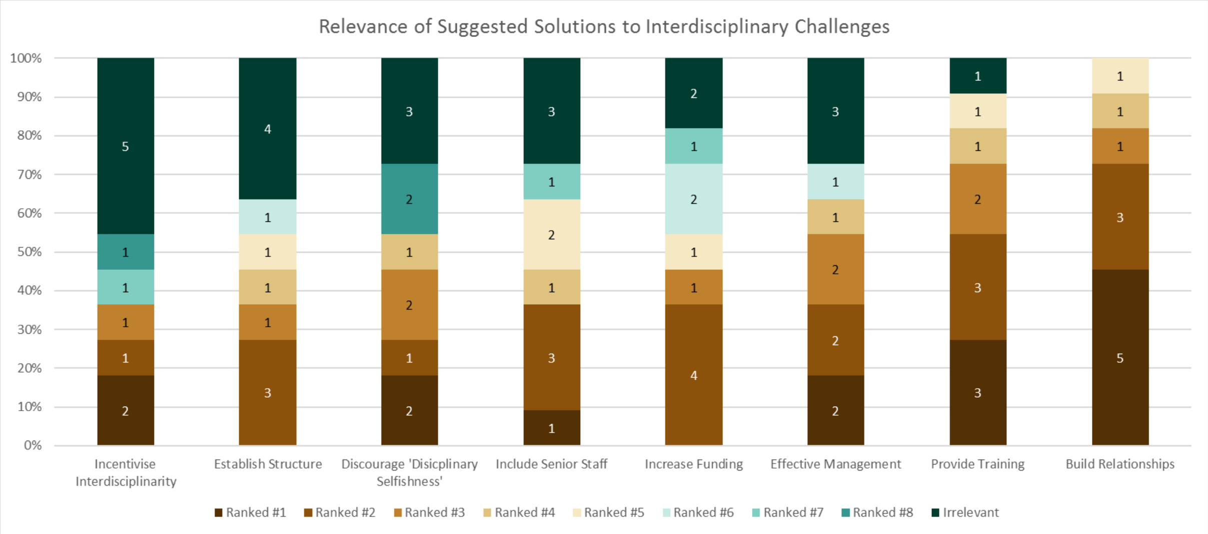


Figure 5.8 One-on-One Interview Results – Relevance of Suggested Solutions to Interdisciplinary Challenges [11 interviews]

From the suggested solutions, Build Relationships was ranked as the #1 solution by many [5], #2 by some [3] and #3, #4 and #5 by the rest [1, 1 and 1, respectively). It is again interesting to note that no one believed Build Relationships to be irrelevant. Provide Training also emerged as a relevant solution, ranked #1 [3], #2 [3] and #3 [2] by most interviewees; one [1] ranked it #4, one [1] as #5 and only one [1] felt it was irrelevant. Effective Management was also considered important by many (ranked #1 [2], #2 [2], #3 [2], #4 [1] and #6 [1]), though three [3] interviewees thought it was irrelevant. Of all the suggested solutions, Incentivise Interdisciplinarity was considered irrelevant by many interviewees [5] or ranked quite low (ranked #7 by one [1] and #8 by another one [1]). This may be because they feel there are already incentivised opportunities in IDR or that other solutions are more important or tenable. Indeed, incentivising IDR would probably have to be at an institutional (or higher) level; whereas, one may work on improving their relationships or seek out training resources on an individual level. Some comments of interest from the interviewees with regard to the suggested solutions were as follows:

> "'[Build] Relationships' is the key... Because when you build relationships, the lines of communication are open, [and] when the lines of communication are open, you build understanding between various parties within an interdisciplinary project and that's where the learning takes place." (Participant B)

> "This [Provide Training] kind of resonates [with me] just as a researcher in general, about the kind of people who were particularly magpies about the information that they have and the power that they hold within that information. It was important to know that the people who were computer savvy were sitting alongside people who weren't, and they had to train one another." (Participant F)

> *“We were forced to do this [Incorporate Effective Management Practices to* Construct Clear Objectives and Evaluation] by our funders and I think that it was *extremely important.”* (Participant G)

Interviewees were then thanked for their time and the interviews were brought to a close; they were also given a business card of the interviewer, should they have any questions or if there was a need to contact them in the future. Furthermore, should at any point the interviewees wish to have their interviews withdrawn from the study, they were reminded to let the researcher know so that their responses could be removed and any recordings of their interviews could be destroyed. Afterwards, notes from the interviews were recorded (A.3.2 Interview Recordings and Outputs, A.3.3 Interview Notes), highlighting important points that came out of them, from which the quotes and data from this section have been derived.

5.1.5 Discussion

The outcomes from the interviews reaffirmed certain findings from the previous chapter and also helped identify some new ones. With regard to GIS platforms, most had experience with QGIS and ArcGIS; this is understandable, as both of these have been said to be the top two platforms used in the GIS industry (Mapping Out the GIS Software Landscape, 2016). The preference for QGIS over ArcGIS could also possibly be explained by the fact that all interviewees worked within academia; as QGIS is an open source technology, those at universities are more likely to adopt it, given a growing culture of openness that is becoming part of the core of academia’s own culture (Wiley, 2006). Including web GIS platforms, these results correlate with those from 4.2 Online Survey that also identify ArcGIS, web GIS and QGIS platforms as those most had experience with. When using those platforms and searching for information on how to do tasks with them, the interviewees predominantly preferred to ask a more experienced person, do an internet search or watch a video; doing a tutorial was preferred a little less, and considered on the same level as posting on a forum, which was not considered very effective in the Online Survey. Nevertheless, value was seen in structured learning resources, as almost all interviewees expressed interest in attending a short course in GIS, with most preferring a face-to-face one. Time Constraints and the Knowledge Gap (“Difficulties Related to Collaborating with Other Disciplines”) were considered the most relevant challenges in IDR to many, followed by Personality Conflicts and Lack of Effective Management; however, this is somewhat at odds with the outcomes from 4.1 Google Scholar Analysis. The Knowledge Gap issue in both were considered the top challenge and Personality Conflicts was also recognised in both as relevant to many interdisciplinary researchers. Time Constraints and Lack of Management, though, were considered more of an issue in the interviews than in the Google Scholar Analysis and "Problems Being at the Interface Between Disciplines" (Disciplinary Conflicts) was more prevalently identified as an issue in the Google Scholar Analysis than in the interviews. As for the suggested solutions, those largely seem to reaffirm the findings from the Google Scholar Analysis, as the interviewees preferred Build Relationships and Provide Training.

Language, as identified as a possible point for further investigation from the survey (4.2.4 Discussion), did emerge as an issue when discussed with interviewees, who were all native English speakers. Disregarding the nuances of how conflicts or misunderstandings of disciplinary language may affect learners is a huge oversight, not only on the part of those making GIS resources, but also for how it may potentially dissuade those learning GIS from using and applying it in innovative, interdisciplinary ways. As identified in 2.1 The Current State of Interdisciplinary Research, interdisciplinary research will describe/define the research questions in language from all disciplines involved, thus creating a common understanding of language.

Further investigating issues with disciplinary jargon, interviewees were asked how they formed search terms when looking for information online. The following are comments from interviewees on how they would form their searches:

> "I would generally put whatever software I was using [as a keyword] first, so if it was using QGIS, put that in first, and I knew a few more technical terms at the time, I wouldn't have known 'digitisation', though, I was thinking, I'd put the task I was looking to do, say, 'enter point information how'." (Participant D)
>
> "I would go, 'shapefile misaligned problems CRS' just to see what would come up. I'd have a fair idea, I've already used some of the terminology, but to be honest I thought it was much more difficult to find a clear answer to it. I think it could be much clearer." (Participant F)
>
> "*… use your keyword search, but then just add 'shapefile'... you won't get so* many web pages about data, you'll start to get pages WITH data." (Participant I)
>
> "*[Example search would be] 'How to get information from polygons to point QGIS'*." (Participant J)
>
> "*[Example search would be] 'Create Centroid QGIS'*." (Participant K)

This highlighted that learners not only try and search for answers specifically linked to the platform they use, but that they must also build an understanding of GIS concepts and terminology in order to ask questions in a way that may have a better chance of leading them to the answers they were seeking. As described by one interviewee:

> "The frustrating thing is that I think there's help out there for everything that you want to do, but even if you put in all the terms you can think of, it still might not come up, and it takes ages searching through things that are irrelevant, but

> you're not sure if the things you're looking at are relevant or not, because you're not sure what it is you're trying to do. Sometimes you spend an hour trawling *through forums thinking 'I'm not sure if this is going to help me, or not.'"* (Participant J)

This issue is extremely interesting because if it can be understood how learners form this vocabulary and go about searching for information, resources may be tailored in a way to incorporate commonalities so that they may be more easily discoverable. However, once interviewees had completed the initial learning process with GIS, they were unable to precisely recall specific issues they encountered from the learning but could describe more general challenges. To address this, further work was undertaken, in the form of asking those who were currently learning GIS to keep Learning Diaries and note down information with regard to problems they encountered and how they went about solving them. This work is described in the next section.

5.2 Learning Diaries

5.2.1 Introduction

Work undertaken in the previous chapter provided an overview understanding of issues interdisciplinary researchers faced when learning GIS and GIS concepts. Complementing the one-on-one interviews in exploring these topics in a more intimate way so that deeper understandings may investigated, another method utilised was learning diaries. Learning diaries may be defined as learners' written reflections on their learning experiences and outcomes, kept over time (Nückles et al., 2004). The aim of these is to stimulate a deeper processing and sustained retention of the learning material (Nückles et al., 2004).

The usefulness of incorporating diaries into educational practices with GIS have already been piloted as well. Comber et al (2008) explored students' developments in spatial awareness in Year 10 (Key Stage 4) by asking students to complete a learning diary at the end of each session. Students were able to share immediate positive and negative experiences by recording them as they happened, which in this study helped to inform changes to future educational work. This was ultimately the aim for the research of this report, and so learning diaries were a wholly appropriate method to use for data collection and learning reflection.

5.2.2 Methodology

To aid this research, interdisciplinary researchers who learned GIS were asked to keep learning diaries that would be collected and reviewed; these learners came from a variety of circumstances. One major source of the diaries of this work were the students at the Development Planning Unit (DPU) at the Bartlett School of Graduate Studies.

They were initially taught GIS as part of one of the preliminary case studies of this work in 2012 (3.3 Development Planning Unit (DPU)). Through a continued relationship, students were taught GIS (face-to-face) in 2014-2016 and some of this cohort contributed some diaries to this research [16]. These students, coming from a variety of disciplinary backgrounds (Spanish, Political Science and Environmental Science, to name a few), were taught GIS and geospatial tools to use in their work with communities in Lima, Peru to better understand water access rights issues that those communities may face. Teaching materials for practicals with these students were based on this context, using relevant data, and delivered for QGIS. This GIS platform was used as it is open source software that would be available to others not affiliated with the University in Lima, if they wished to do further GIS work, circumnavigating licencing issues that exist with proprietary platforms (e.g. ArcGIS). These students were also taught how to use ArcGIS Online, a web GIS platform, to create a Story Map, which is a digital map that includes a narrative and media to tell a story. The materials for this were again set in the context of water access rights issues in Lima, Peru[7]. A second group who contributed diaries to this research [5] were students from the Masters in Geography Education at the Institute of Education (IOE). These students were taught (online) the same lessons on how to use ArcGIS Online to create a Story Map so they may use it as a teaching tool with students in Geography classes. Finally, a few diaries [2] were kept by and collected from various interdisciplinary researchers associated with Extreme Citizen Science (ExCiteS) research group (again, one of the preliminary case studies [3.2 Extreme Citizen Science (ExCiteS)]) who wished to learn GIS platforms, such as QGIS and ArcGIS Online, and contributed diaries to this research in exchange for access to the teaching materials (online) that were constructed as part of this research. A summary of these groups' learning experiences for which diaries were kept is detailed in Table 5.5.

Table 5.5 Details of Learning Experience for Learning Groups

Group	Journal Numbers	Learning Medium	Platforms	Total Time Allotted
IOE	#1-#5	Online	ArcGIS Online	1 week
ExCiteS	#6-#7	Online	QGIS and ArcGIS Online	(Self determined)
DPU	#8-#23	Face-to-face	QGIS and ArcGIS Online	9 hours

[7] These initial teaching materials used with this group would later be adapted and incorporated into the developed learning resource, GIS Lessons for You, the construction of which will be detailed in Chapter 7.

Bearing all these groups in mind and the variety of backgrounds learners came from, familiarity with GIS could not be expected and many were complete beginners when it came to using GIS. To detail their learning journey, these learners were asked to keep a learning diary to record the following information whenever they might need to do something in the GIS that they did not know how to do:

1. THINK: What are you trying to do in the GIS application?
2. SEARCH: Where are you searching for the information? What are your search keywords?
3. REPORT: How long did you search for the answer? Did you find the solution? If so, where?

It was hoped that through this, it could be understood how learners go about finding information when they are learning GIS and, from this, how materials, online or otherwise, could be better structured in a way that makes them easier to find and understand by interdisciplinary learners. By keeping a diary, learners could also capture and reflect on current experiences as/when they happen, before they are lost or forgotten. In total, 23 diaries were completed and collected between October 2014 and December 2016 and copies of all diaries may be found in A.4.1 Learning Diaries Scans. Each diary was read and emerging themes were recorded and tabulated to see if there were any trends amongst the learning experiences. Completion time of the learning activities, whether it was the activity in ArcGIS Online or QGIS, was also noted, if that information was provided. Finally, relevant quotes from learners were recorded to share as part of the results and explore further in the discussion.

5.2.3 Results

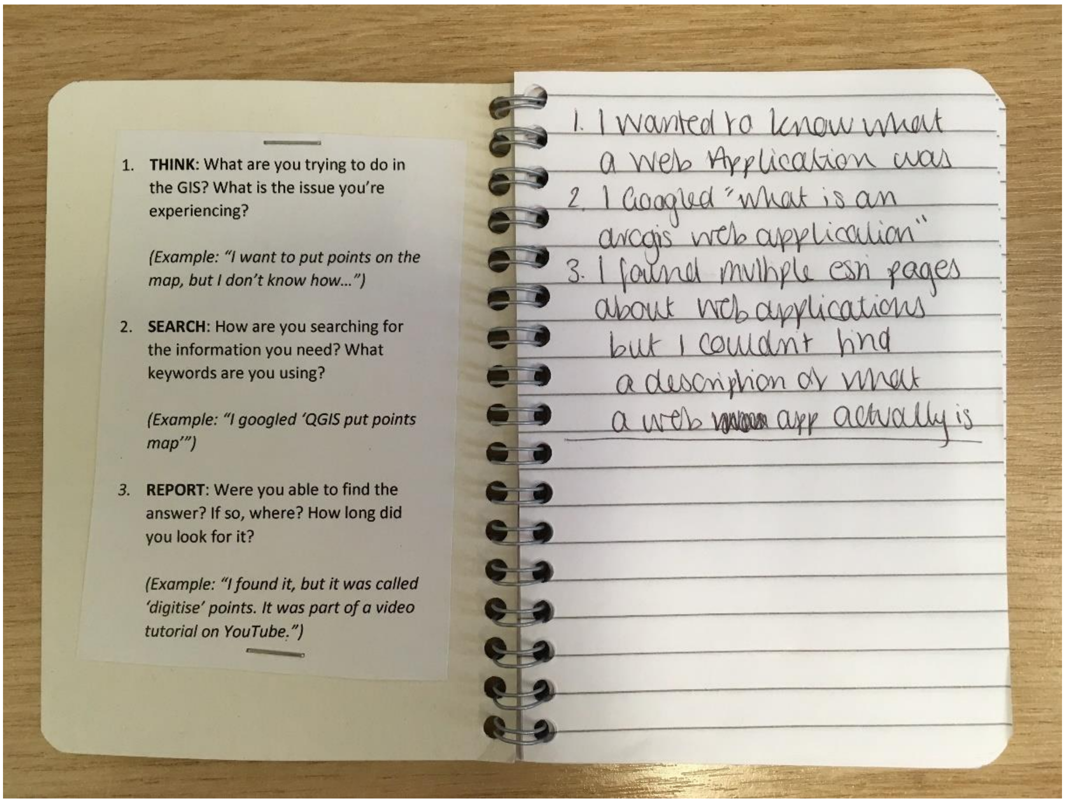


Figure 5.9 Learning Diary Example

Figure 5.9 shows an example diary that was collected from one of the learners[8]. From reading each of the diaries, for those who reported it, it was found that IOE students finished the ArcGIS Online materials in an average of 5 hours [5 of the 5], the ExCiteS researcher who recorded time finished the QGIS materials in about 6 hours [1 of the 2], and though individual timings were not kept for the DPU students, QGIS practicals came to 6 hours in total (two 3 hour sessions) and the ArcGIS Online practical was 3 hours. People also reported that, when looking for answers to questions, they utilised internet searches, watched videos and asked people who were more familiar with GIS for help. Some issues originated from hardware/network problems or from the software itself (e.g. bugs, program crashes, compatibility issues, etc.), though many of their misunderstandings had to do with vocabulary and concepts/ideas that were found to be confusing and unfamiliar in respect to the learners' home discipline. Some examples of which were "layers", "Coordinate Reference System (CRS)", and "pre-set projection".

When encountering these issues with QGIS and ArcGIS Online, it was recorded in the journals that some people blamed themselves. Two [2] of the IOE students experienced

[8] Scans of the learning diaries can be found on the included USB drive, as detailed in A.4.1 Learning Diaries Scans

network issues, which certainly affected them as the class was an online one, and the two [2] ExCiteS researchers and four [4] of the DPU students reported issues with the software (e.g. crashes, version specific bugs, data issues, etc.). When issues with software and usability arise, McCoy (2002) notes that it is quite common for users to, perhaps at least subconsciously, blame themselves. Indeed, as exhibited in the diaries, ten [10] show circumstances of people self-denigrating or blaming themselves for issues with the technology, such as:

> "*… I question whether it would take a tech*-savvy youngster as long." (IOE, Journal #1)
>
> "*I probably did something wrong…*" (ExCiteS, Journal #7)
>
> "I know you [researcher*] said it a million times before but I am a bit slow…*" (DPU, Journal #10)
>
> "*I'm not very good with technology…*" (DPU, Journal #23)

Regardless, despite the difficulties, many still saw the potentially useful applications of GIS and included positive reviews. Some comments from the diaries are as follows:

> "… I realize that within my context it will make citizenship education classes more interesting and participatory." (IOE, Journal #4)
>
> "It is clear that GIS are prevalent throughout many fields and needs to be incorporated into geography education as a priority." (IOE, Journal #5)
>
> "*I've extremely enjoyed these GIS sessions as I've learnt a lot of skills…*" (DPU, Journal #13)
>
> "*I'*m hoping to learn to use this tool really well in order to incorporate this skill in my future work/real life." (DPU, Journal #16)
>
> "Overall, it was a really informative experience for my first encounter with GIS!" (DPU, Journal #23)

5.2.4 Discussion

The diaries provided insight into the current learning experience of the learners who kept them and, overall, it seems those experiences were positive, in spite of issues experienced. The IOE students may have taken longer with the ArcGIS Online materials than the time given to the DPU students for that particular practical due to taking it entirely online. This may have required them to work through certain problems they may have encountered without immediate assistance from someone. The ExCiteS researcher who was able to get through all the materials in a shorter amount of time did have other GIS experts nearby and asked help from them, which may have played a role in their completion time. Between all diaries, though, the mixture of informal methods used for finding information (e.g. internet searches, watching videos, asking a more experienced person, etc.) and issues experienced with language mirror the results from the online survey (4.2 Online Survey) and interviews (5.1 One-on-One Interviews). The diaries were also useful in highlighting issues that were encountered when using QGIS and ArcGIS Online and the propensity for users to blame themselves. However, as said by Norman (2013), "When you have trouble with things – whether it's figuring out whether to push or pull a door or the arbitrary vagaries of the modern computer and electronics industries – it's not your fault. Don't blame yourself: blame the designer." (p. x). Perhaps, from this research, improvements may be suggested not only to GIS software, but to associated learning resources as well. These learnings have been incorporated into the teaching resource that will be described in Chapter 7, which enables further exploration of suggested improvements put into practice.

The findings from the learning diaries, though, may be considered limited, due to a number of factors. It was hoped that based upon the initial structure given, learners would use that to record any and all problems they faced when using the GIS; however, it was often the case that learners recorded an overview to their experiences of using GIS, with more generalised terms/concepts, such as "things being difficult". Learners often did not elaborate on what those things were and simply said that they did not understand something; further details on what they did in order to find more to try and understand it were not regularly recorded. The amount of information recorded in journals was also an issue, as some, beyond writing down the structure of what it is they were to record, had written little or nothing else. This may have been because people were more focused on learning than they were in recording issues encountered when learning or, based upon the amount of work they may have had to do, this may have been an extra piece of work that they were not interested in taking part in. The total number of diaries collected could have also been much higher, as over the years, over 100 students took part in the DPU GIS classes; however, only sixteen [16] in total were collected. This may be attributed to the fact that the educational situations in which it was requested that learners keep and record a GIS learning diary were either optional parts of formal programmes or were completed on the researchers' own time. Bearing this in mind, the diaries were not a requirement and so, the learners' use and return of them was largely based on good will and follow up, when possible, from their course tutors.

Some suggestions may be posed in order to potentially improve viability of using diaries as a tool for recording and reflecting upon the learning experience for the future. A digital diary, perhaps, which would not only allow learners to record their learning journey electronically, possibly through a web platform or browser extension, may be an improvement over a more traditionally kept one. This could not only be accessible across platforms through a single login, but also automatically record keywords used as part of internet searches, may better facilitate the capture of this kind of information. This, however, could pose logistical issues such as finding (or creating) a platform with such capabilities and the learner allowing their search history to be shared. Alternatively, temporary accounts could be created and browser histories could be harvested (or screens could be recorded) as part of a focused workshop on learning GIS to further explore information searching behaviour, circumnavigating the need to record each search in the diary. Such work was undertaken as part of this research, which is detailed later in Chapter 8. Regardless of the medium, though, it would be recommended that in order to achieve meaningful results when using learning diaries that they are required as part of the course, if that is possible to implement, and regularly checked to direct what is being recorded to ensure outputs are useful.

5.3 Interviews and Learning Diaries – Summary of Findings

The interviews and diaries did allow for further exploration of some of the topics from the previous chapter as well as shared some specific examples of experiences from people who learned GIS. ArcGIS, QGIS and web GIS platforms seem to be prominently used and when searching for information on them, internet searches, videos and asking more experienced people often seem to be methods utilised. With regard to interdisciplinary challenges, the Knowledge Gap and Personality Conflicts seem to be the issues most commonly faced, and suggested solutions of Building Relationships and Provide Training seem to be most often employed. Language was identified as a possible issue and further investigated through the interviews and diaries; it can be seen from them that vague, general terms can be confusing and discipline-specific jargon can be frustrating to deal with. Regardless, there does seem to be some level of necessity in building the disciplinary vocabulary of GIS, as researchers often incorporated some of these words into search terms used to find answers to issues encountered. How these search terms were built, though, was limited to what interviewees could recall and to what those who kept diaries felt like recording, so further work may be suggested to find out more about their construction.

With that information, any learning resources may be made easier to understand and discover, whether used as part of online or face-to-face teaching. Ultimately, it may be said that it is important to do what is possible to improve the learning experience for GIS learners, as they are already prone to blaming themselves for hardware/software issues that are largely not their fault. Therefore, if learning resource quality and usability can be improved through careful selection of a relevant problem set, language that makes sense to the learner in an interdisciplinary setting and tailored to the GIS platform they are using, it may be possible to expedite learning and application of GIS. These findings, which are based on a sound foundation and provide evidence that begins to verify some of the hypotheses of this work, may be used to suggest a conceptually understandable method for practical application. In the next chapter, a series of potential frameworks will be explored with respect to this work to suggest one that may be used to advise on future practices in improving GIS learning resources for interdisciplinary researchers.

Chapter 6 - A Suggested Framework for Learning GIS in IDR

This research has expanded upon Loo's diagram (Figure 2.1) by incorporating further educational theories that may be relevant to IDR (Problem-Based Learning, Context-Based Learning, Community of Practice) and new links between theories. These theories, highlighted in red, seem best aligned within the Education category of Loo's diagram; however, they link to others discussed in 2.2 Educational Approaches in the Psychology and Management categories, which has also been highlighted in red. Including the theories that were added to the diagram, existing ones from the original that were linked to them were reviewed for this work and are highlighted in green. This has helped to facilitate a cross-theoretical understanding of learning approaches, their strengths and weaknesses and how and why CBL may be a conducive approach for IDR.

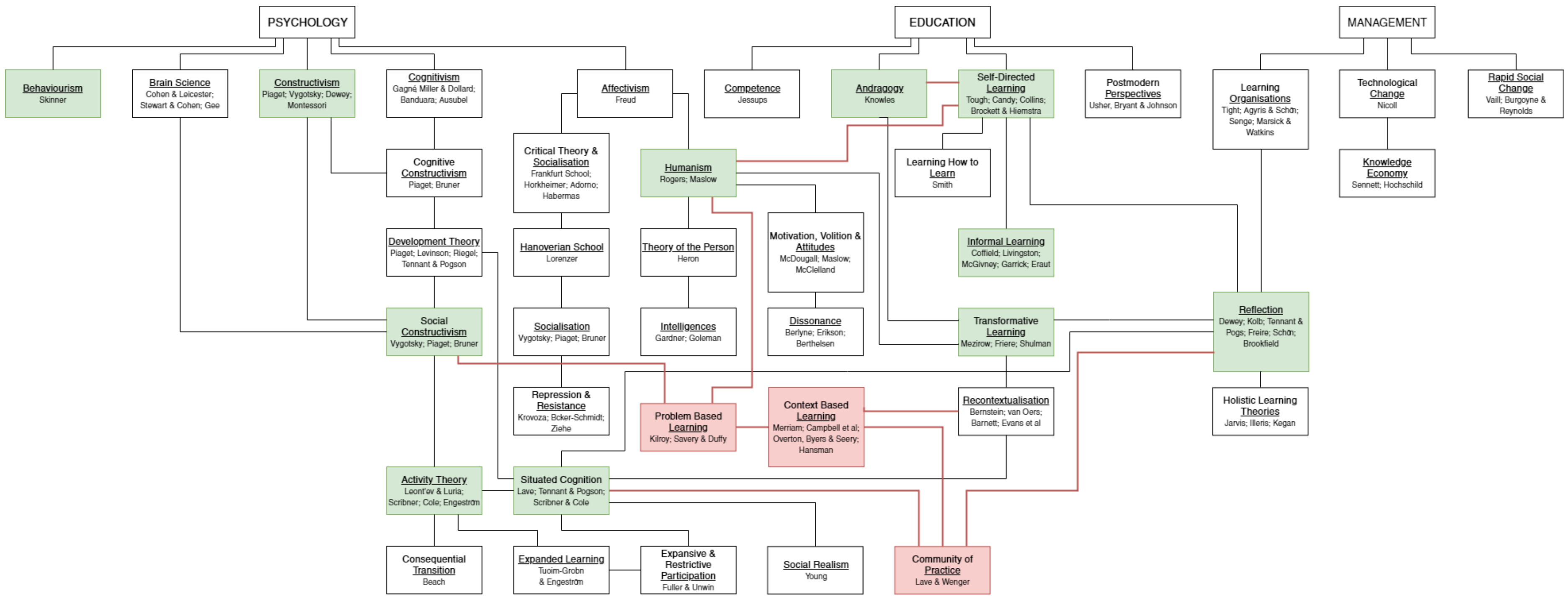


Figure 6.1 Updated Theories of Learning Diagram

On top of learning approaches, the previous chapters have also investigated interdisciplinary research (IDR) challenges, suggested solutions, Geographic Information System (GIS) concepts of relevance and learning approaches employed by interdisciplinary researchers who had either previously learned GIS (Chapter 4), or were currently learning it as part of their research (Chapter 5). Individually, the areas of GIS, educational approaches and IDR have been researched by many, with some investigating the intersections between two of them. However, studies investigating the nexus of these three knowledge domains – interdisciplinary GIS educational approaches (as represented in Figure 6.2) – are extremely limited; this is one of the novel and key contributions of this body of research.

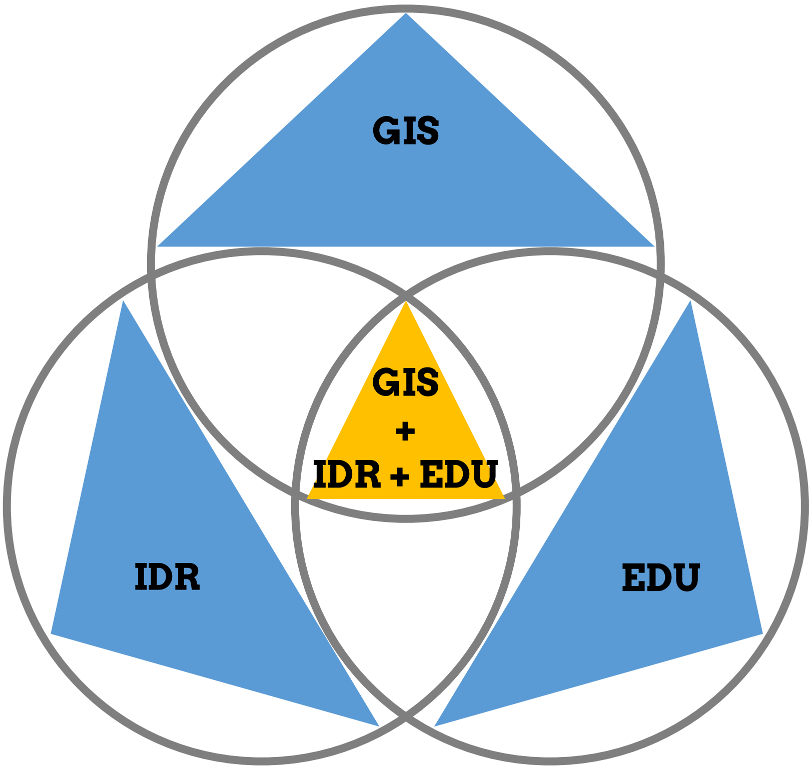


Figure 6.2 *Diagram representation of this research's areas of i*nterest and their nexus

Though Figure 6.2 is helpful for providing a visual representation of the research undertaken, it is necessary to either align it with or create a conceptual framework based on sound theories and evidence for practical application. As mentioned, given that the overlap between all three areas is under researched, initial explorations have indicated that such a framework does not yet exist. Therefore, it is necessary as an exploratory step to first evaluate existing ones from the individual research areas or their intersections to see if any could lay the foundation for or be modified to put forward a new framework as an output of this research.

A series of frameworks were reviewed and what began to emerge from those that were relevant was that they revolved around certain themes, based on the knowledge domains. Relevant educational frameworks seemed to focus on “how to learn”, interdisciplinary frameworks on “how to manage information” and those specifically on GIS were about “how to integrate GIS”. These are themes that are relevant to interdisciplinary researchers learning to use and apply GIS, and so two from each area based upon their applicability to the work undertaken were selected for further investigation. Frameworks that were to be considered needed to embody the following:

- Aspects of learning with technology
- The ability to apply framework aspects to other knowledge domains, specifically about GIS (if possible)
- They should not be generalist or vague about applications.

The following sections will detail relevant frameworks, analyse their strengths and weaknesses and afterwards suggest a possible new framework for improving the learning experience for when interdisciplinary researchers wish to learn GIS. The frameworks that were reviewed are as follows:

- Technological Pedagogical Content Knowledge (TPACK) Framework – Framework that focuses on the intersections and synergy between technological, pedagogical and content knowledge for effective teaching. (Shulman, 1987; Mishra & Koehler, 2006)
- Dimensions and Antecedents of Virtual Learning Environment (VLE) Effectiveness – Framework to measure the effectiveness of Virtual Learning Environments with respect to human and design dimensions. (Piccoli, Ahmad & Ives, 2001)
- Conceptual Framework of Inter-Organizational GIS Activities – Framework that builds on GIS data sharing classes, needs, opportunities, willingness, incentives, impediments, capabilities and resources. (Nedovic-Budic & Pinto, 1999)
- GIS Development Process Matrix – Framework that seeks to improve the update and implementation of GIS in organisations by addressing issues around people, organisations, goals, change and technology. (Onsrud & Pinto, 1991; Campbell, 1992; Obermeyer & Pinto, 1994; Anderson, 1996)
- Conceptual Framework for the Collaborative Spatial Delphi (CSD) method - Framework that sets out a participatory planning process for implementation and use of GIS in the decision making process. (Balram, Dragicevic & Meredith, 2003)

- CyberGIS Framework - Framework that sets GIS, Spatial Analysis, Cyber Infrastructure as interlinked fields with computational intensity as a central unifying role. (Wang, 2010)

6.1 Evaluating Educational Frameworks – How to Learn

One of the investigative areas of this research is focused on how people learn and how that process may be improved for GIS. Therefore, educational frameworks that can be used to structure the findings so far around how people learn may provide an ideal basis for this research. Educational frameworks may focus on theoretical understandings of learning itself, or perhaps advise on best practices in forming and delivering learning activities and materials. These may begin to touch upon aspects of relevant to this research; however, neither would be ideal, as the former would lack information on practical delivery and the latter may not fully take into consideration the epistemological nuances for GIS and/or interdisciplinary learning.

The two educational frameworks to be discussed, the Technological Pedagogical Content Knowledge (TPACK) Framework and Dimensions and Antecedents of Virtual learning Environment (VLE) Effectiveness, incorporate a theoretical foundation that also focuses on practical application. Both are concerned about the use of technology in educational approaches and have aspects that focus on the role of the educator in construction and delivery of the learning experience. These will be described in greater detail to understand their relevance to this research and whether they may be used as a basis for or guidance in the construction of a framework for learning GIS in IDR.

6.1.1 Technological Pedagogical Content Knowledge (TPACK) Framework

It has been said that the intersection between technological, pedagogical and content knowledge guides effective teaching; the art and science of teaching is the negotiation of and synergy between these three forms of knowledge (Koehler & Mishra, 2008; Mishra & Koehler, 2006). Initially formed of pedagogical knowledge and content knowledge (Shulman, 1987), Mishra and Koehler (2006) amended the framework to add technological knowledge, forming the TPACK framework as known today (Figure 6.3). This framework recognises not only the importance of each of these elements, but their overlaps as well. Each part and their intersections, with concepts summarised afterwards in brackets, as described in Koehler (n.d.) are as follows:

- Pedagogical Knowledge (PK): Teachers' deep knowledge about the processes and practices or methods of teaching and learning. [Learning Approaches]

- Content Knowledge (CK): Teachers' knowledge about the subject matter to be learned or taught. [Subject Area Expertise]
- Technological Knowledge (TK): Knowledge about certain ways of thinking about, and working with technology, tools and resources. [Understanding & Application of Technology]
- Pedagogical Content Knowledge (PCK): The teaching of specific content. [Teaching Subject Area Expertise through Learning Approaches]
- Technological Pedagogical Knowledge (TPK): An understanding of how teaching and learning can change when particular technologies are used in particular ways. [Learning Approaches for Understanding & Application of Technology]
- Technological Content Knowledge (TCK): An understanding of the manner in which technology and content influence and constrain one another. [Teaching Subject Area Expertise through Understanding & Application of Technology]
- Technological Pedagogical Content Knowledge (TPACK): The basis of effective teaching with technology, requiring an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge to develop new epistemologies or strengthen old ones. [Teaching Subject Area Expertise and use of Learning Approaches for Understanding & Application of Technology]
- Contexts: Described as the unique situational factors associated with, but not limited to, individual teachers, grade-level, school-specific factors and demographics. It is also noted that no single combination of content, technology and pedagogy will apply for every teacher, every course, or every view of teaching. [Institutional Learning Environment]

Figure 6.3 Technological Pedagogical Content Knowledge (TPACK) Framework

TPACK is noted as addressing a theoretical gap in providing more of a foundation for research into educational technology (Thompson & Mishra, 2007; Schrum et al, 2007); as GIS begins to play a more prominent role in education, particularly as it is now a required part of the National Curriculum in England for Geography in Key Stage 3 (Department for Education, 2014, p. 91), TPACK can act as a guide for implementing GIS in an educational setting, in Key Stage 3 or beyond, in a meaningful way. With regard to its use for professional development for experienced teachers, TPACK is also noted for promoting "… both autonomous and collaborative instructional decision-making while simultaneously encouraging open-minded consideration of new instructional methods, tools, and resources." (Harris, 2008, p. 267); therefore, using TPACK to introduce GIS to educators as part of their professional development might improve its chances for uptake. However, though meant to act as a generality, "technological knowledge" as a concept may not be specific enough about the knowledge associated with learning and using GIS; GIS is known to be difficult to use (Liu, Tan & Xiang, 2012) and so it is questionable if TPACK may be able to mitigate some of these domain specific issues. Even with materials and learning activities structured in a way that makes use of TPACK, learners must be motivated to learn the subject (e.g. GIS) – something TPACK does not necessarily account for.

6.1.2 Dimensions and Antecedents of Virtual Learning Environment (VLE) Effectiveness

Virtual Learning Environments (VLE), which share similarities with GIS in that they both are able to provide access to a wide range of resources, are defined as "computer-based environments that are relatively open systems, allowing interactions and encounters with other participants" (Wilson, 1996, p. 8). Piccoli, Ahmad and Ives (2001) propose a framework (Figure 6.4) on the dimensions and antecedents for measuring the effectiveness of VLEs, which centrally recognises human and design dimensions to VLEs and metrics for measurement. The human dimension is broken down into aspects associated with students and those with instructors, while the design one focuses on the learning model, technology used, the learner's control, content (and associated knowledge) and necessary interaction with materials. Finally, the effectiveness of the VLE can be measured through metrics associated with student performance, perceived self-efficacy and overall satisfaction.

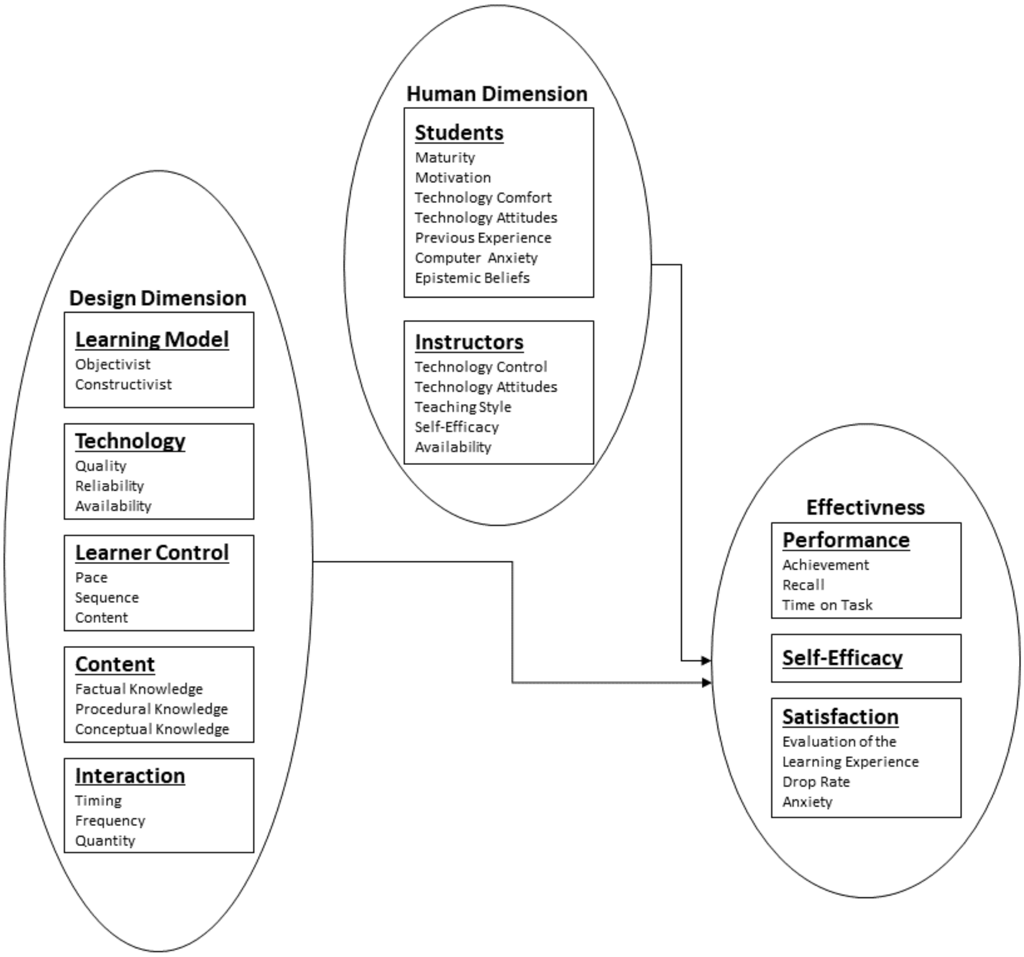


Figure 6.4 Dimensions and Antecedents of VLE Effectiveness

Though largely aimed at measuring the effectiveness of VLEs, there are many correlations in this framework to learning GIS – the structure of learning activities, goals of the students and teachers and the effectiveness of all elements combined at facilitating uptake of the technology. Indeed, the importance of web technologies for learning can be recognised, as 100% of the 94 higher education institutions surveyed in the UK use VLEs (Walker et al, 2014, p. 20); similarly, web-based learning technologies for GIS are becoming increasingly commonplace in higher education (Clark, Monk & Yool, 2007). In these, as well as self-directed or informal learning situations, self-efficacy and learner control are also important parts of this framework, which may mean this could act as a guide for structuring technologies and/or materials for such purposes. However, as stated, this framework is about VLEs and so certain nuances associated with GIS (e.g. spatial thinking, GIS concepts, etc.) may not be able to be appropriately addressed. Regardless, appropriate to both, it has been acknowledged that web-based learning for and with technologies can sometimes lead to learners feeling isolated (Brown, 1996; McKimm, Jollie & Cantillon, 2003), so educators will need to monitor students and adjust tactics, as necessary, to ensure students are satisfied with their learning experience.

6.2 Evaluating Interdisciplinary Frameworks – How to Manage Information

IDR is a potentially vast area of research, depending upon the collaborative efforts of those from other disciplines. Bearing that in mind and the innovative direction of such research, constructing a single framework that could be applicable to many such projects may be difficult. As such, when reviewing examples that might be relevant to this research, they may have either been too vague or were for specific applications that did not consider dimensions such as educational approaches or technologies, like GIS. Therefore, GIS literature was explored to identify ones that could be considered to have interdisciplinary applications. What largely emerged was that relevant ones focused on data and information management and sharing between entities.

The two frameworks in this section, which are the Conceptual Framework of Inter-organizational GIS Activities and the GIS Development Process Matrix, are about use of information, namely geographic information, and may be extended to IDR. They both have aspects on how information is disseminated between people and suggest methods for doing so. Their focus on outcomes is also relevant to IDR, as direct applications of learning are of importance to adult, and therefore interdisciplinary, learners. As such these frameworks may also provide a basis for or guidance in constructing one for learning GIS in IDR and will be discussed in the following sections.

6.2.1 Conceptual Framework of Inter-organizational GIS Activities

Nedovic-Budic and Pinto (1999) propose a conceptual framework that builds off of a comprehensive list of factors relevant to GIS data sharing, initially compiled by Kevany (1995); these include sharing classes, organizational environment, need for sharing data, opportunity to share data, willingness to share data, incentive to share data, impediments to sharing, technical capability for sharing and resources for sharing. The proposed framework takes these factors and derives four general theoretical constructs which are context, motivation, coordination mechanisms (structure, process and policies) and outcomes (Figure 6.5).

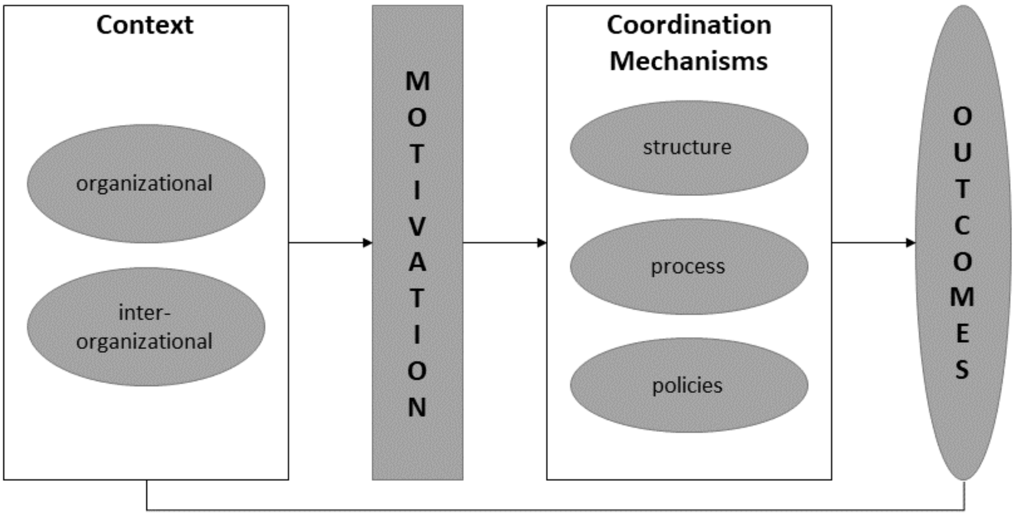


Figure 6.5 Conceptual framework for management of inter-organizational activities

First and foremost, the framework aims to clarify what GIS capabilities may be available to the organisation, to avoid redundancies and improve information dissemination throughout the organisation. This may lead the way to the establishment of an egalitarian structure, which may improve employee morale, and provide a cost-benefit savings to the organisation, leading to the expenditure of finances in other areas. Critiques of this framework begin with the fact that it is not immediately apparent how GIS or geospatial information is an implicit part of it; it is only through reading about the framework that one may understand that GIS is central to it, so that could be better communicated. Furthermore, its suggested structure, outside of creating interdependencies, may also require difficult institutional change and might create internal political issues, as some may feel these changes would infringe upon their domain.

6.2.2 GIS Development-Process Matrix

The GIS Development Process, put forward as a framework that combines the content- and process-model themes identified by Onsrud and Pinto (1991) and the stages described by Campbell (1992) and Obermeyer and Pinto (1994), is suggested for use when considering a broad array of critical issues that have typically been treated in isolation (Anderson, 1996). This framework seeks to improve uptake and implementation of GIS in organisations by addressing five core areas in which issues may arise (people, organisations, goals, change and technology) across the three identified implementation stages (initiation, acquisition and incorporation). An overview of the GIS Development-Process Matrix is given in Figure 6.6.

Phase	Stage I Initiation	 II Acquisition	 III Incorporation
1 Participation (People)	Education champions Form Ad Hoc discussion groups	Involve managers and users Formalize committees	Identify future users Create informal user groups and Ad Hoc task forces
2 Context Evaluation (Organization)	Informal Apply Evolution Matrix	Formal Circulate Surveys Begin GIS Analysis	Informal Continuous
3 Vision Creation (Goals)	Informal Education	Formal Workshops Publish GIS vision, GIS Design	Informal/Formal Focus Groups
4 Change (Change)	Informal Facilitate new partnerships and new ideas	Formal Redefine roles and work flow Evaluate change feasibility Evaluate the GIS vision	Formal/Informal Continuous
5 Technology Implementation (Technology)	Formal Agreements Budgets	Formal Proposals Pilot Projects System purchase and installation Data conversion	Continuous GIS used daily

Figure 6.6 GIS Development-Process Matrix

This framework seeks to simplify the GIS implementation process in organisations, which is recognised as complex, and attempts to address both technical and non-technical barriers to GIS uptake. The framework is also adaptable based upon the needs of the organisation, such that if the immediate objective is to introduce organisation members to GIS concepts, then focus should be put on the initiation phase, with emphasis on technology and people. Alternatively, if analysis and design are the objectives, then focus could instead then be on aspects outlined under technology under the acquisition phase. Participation is listed as a central tenet to this framework; however, such level of involvement may be time intensive or not feasible for certain people in the organisation, which may affect other aspects of the framework. A basic level of knowledge of GIS is also assumed in the framework; if those participating do not have this information, they may feel reluctant to contribute or may not be able to effectively communicate ideas.

6.3 Evaluating GIS Frameworks – How to Integrate GIS

Frameworks associated with learning and information management embody parts of this research; however, another one of importance is on how researchers integrate GIS into their practice. Meaningful application of GIS comes not just from knowing about the tool and how to use it, but also understanding why it is the most appropriate tool for the analyses to be undertaken to deliver the necessary outputs. GIS frameworks that focus on system design or specific analytical processes may be too specific to be relevant to this research, as the focus is more generally on learning and applying GIS. Therefore, those to be evaluated needed to be more about identifying the intended uses of GIS and how to actualise those in practice.

The GIS frameworks investigated are the Conceptual Framework for the Collaborative Spatial Delphi (CSD) method and the CyberGIS Framework. These detail the parts and processes for GIS application, which include problem definition, analysis and collaboration, for successful integration. The following sections will provide further information on how these frameworks may serve as a basis for or guidance in the construction of one for learning GIS in IDR.

6.3.1 Conceptual Framework for the Collaborative Spatial Delphi (CSD) method

The Collaborative Spatial Delphi (CSD) method, proposed as a conceptual framework (Figure 6.6), at its core seeks to include stakeholders as part of a participatory process of planning and the implementation and use GIS as a tool to infuse spatial data and information into the decision making process (Balram, Dragicevic & Meredith, 2003). CSD brings together aspects of knowledge management, focus group theory, systems theory, adaptive management, integrated assessment, visualisation and exploratory analysis and transformative learning. The conceptual framework for the CSD method (Figure 6.7) is divided into the following parts:

1. Level of stakeholder representation
2. Environmental problem definition
3. Systems theory and problem dimensions
4. Integrated assessment, map analysis and visualisation
5. Discursive analysis and transformative learning
6. Monitoring and adaptive management
7. Collaboration and participation effectiveness

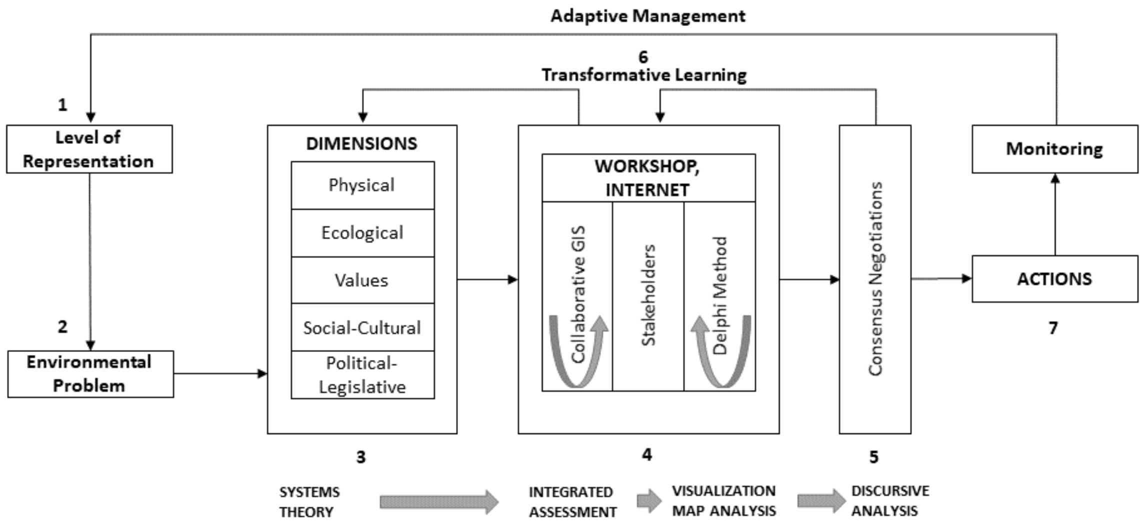


Figure 6.7 Conceptual framework for the Collaborative Spatial Delphi Methodology (CSD)

This framework's focus on collaborative processes may empower people to contribute to and participate in decision making, with GIS acting as an effective tool a part of it. Should potential research be set within communities, this may be an appropriate framework to guide such work. The incorporation of a variety of well-recognised theories and methodologies to form this conceptual framework also strengthens the claims it puts forward. However, it has also been recognised that participatory methods come with their own inherent challenges that need to be taken into account (Mayoux, 2001). Therefore, the implementation of this framework, though it may assist the research, will not necessarily handle issues that may arise with group members during the project (e.g. conflict management, power dynamics, etc.) and the outcome of selected actions may result in the disempowerment of some participants. If group participation is not necessary for the research, though, then this framework may be adapted; however, as participatory processes are central to it, major changes may be needed and as such its strengths may be lost.

6.3.2 CyberGIS Framework

The CyberGIS framework is described as taking "… a holistic approach to synergistically integrate CI [cyberinfrastructure], GIS, and spatial analysis." (Wang, 2010). The National Science Foundation recognises cyberinfrastructure as the comprehensive information technology infrastructure that provides integrative access to interrelated computational components (National Science Foundation, 2007). Applied to GIS, for purposes such as the (possibly distributed) storage and analysis of geospatial data, this opens up new opportunities that may not have been previously possible. The conventional computer-centric architecture model for GIS implementation therefore may be updated to the suggested CyberGIS framework, detailed in Figure 6.8. The framework, at its core, sets CI, GIS and spatial analysis as interlinked fields and computational intensity - complexity and input-output - plays a central role in unifying them; CI enables distributed processing of information (application centric) and allows collaborative problem solving to take place as well (user centric) in a potentially complementary manner. Spatial middleware then facilitates cross-platform communication and management of the CI through established workflows that complement service oriented architecture and component based approaches. All of this is possible through and contributes to data and knowledge, visualisation, high-performance computing and virtual organisation.

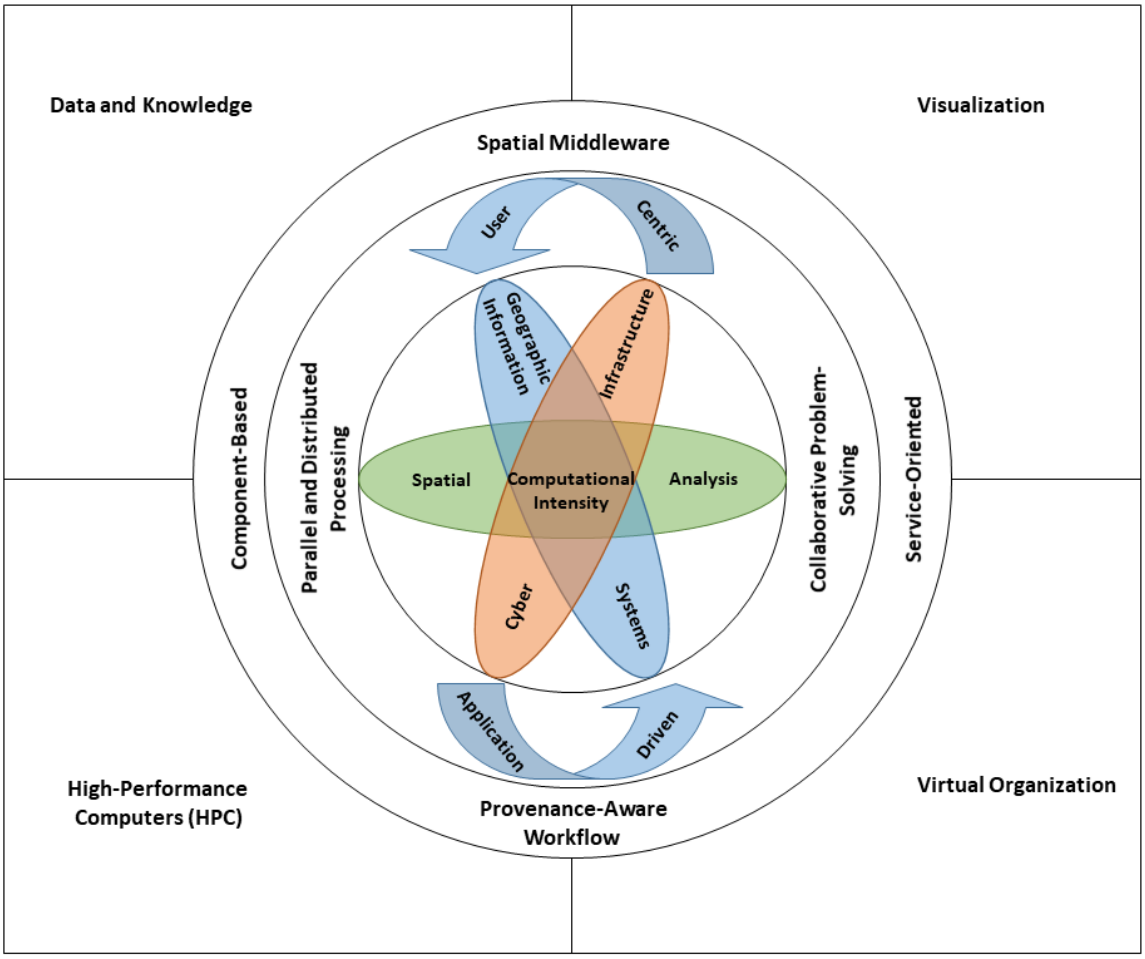


Figure 6.8 CyberGIS framework

The CyberGIS framework provides a strong foundation for the implementation of a GIS, advising on how hardware, software and applications should be set up in a way that prepares them to handle the tasks that may arise. It also provides an understanding of scalability, based upon the processes that are to be implemented and the power of the available CI; this would allow researchers to evaluate work and understand if the CI needs to be updated. Social aspects do not play a central role in this framework;

therefore, if research is centred on or around group dynamics itself, rather than the more mechanical components, this framework may not be appropriate. Indeed, the components of this framework largely seem to be focussed on the interplay of technologies and outputs, rather than providing a better understanding how the inherent processes contribute to or enhance the outputs (e.g. how do aspects of CyberGIS impact the virtual organisation?, how do its components affect the production of understandable visualisations?, etc.)

6.4 Proposed Framework – Modified TPACK with Mapped Research Components

From review of frameworks associated with how to learn, how to manage information and how to integrate GIS, it may be seen how parts of them could relate to this research and how other aspects are not entirely relevant. Table 6.1 provides a summary of all the reviewed frameworks and their potential strengths and weaknesses with respect to this work.

Table 6.1 Summary of Frameworks, Associated Themes, Descriptions, Strengths and Weaknesses

Framework Themes	Framework Name	Description	Strengths	Weaknesses
Educational	Technological Pedagogical Content Knowledge (TPACK) Framework	Framework that focuses on the intersections and synergy between technological, pedagogical and content knowledge for effective teaching	• Provides foundation for educational technology research • Encourages creative, collaborative instructional design	• Technological generalities might miss specific needs of GIS
Educational	Dimensions and Antecedents of Virtual Learning Environment (VLE) Effectiveness	Framework to measure the effectiveness of Virtual Learning Environments with respect to human and design dimensions	• Structure, goals and measures of effectiveness of VLE could be applied to learning GIS • Similarities between VLEs and GIS as technologies for teaching	• VLE findings might not be comparable to GIS nuances • Focus on online learning does not consider learner engagement
Interdisciplinary	Conceptual Framework of Inter-Organizational GIS Activities	Framework that builds on GIS data sharing classes, needs, opportunities, willingness, incentives, impediments, capabilities and resources	• Clearly outlines organisational diffusion of technology capabilities	• GIS not explicitly named within it • Does not consider issues of institutional change and politics
Interdisciplinary	GIS Development Process Matrix	Framework that seeks to improve uptake and implementation of GIS in organisations by	• Simplifies and defines phased implementation for GIS	• Participation named without including time considerations

		addressing issues around people, organisations, goals, change and technology		• Assumed basic level of GIS knowledge
GIS	Conceptual Framework for the Collaborative Spatial Delphi (CSD) method	Framework that sets out a participatory planning process for implementation and use of GIS in the decision making process	• Collaborative process may empower learners and encourage engagement • Strong theoretical foundation	• Does not consider personality issues or group dynamics with respect to selected actions
GIS	CyberGIS Framework	Framework that sets GIS, Spatial Analysis, Cyber Infrastructure as interlinked fields with computational intensity as a central unifying role	• Advises on hardware, software and applications • Scalable deployment based on assessing user needs	• Social aspects not central to framework • Focus is on GIS outputs rather than how GIS can enhance desired outputs

Bearing in mind that the aim of this work is to better understand the learning experience of the interdisciplinary learner when learning GIS, any framework as an output of this work will be focusing more so on educational aspects than the other research areas (GIS and interdisciplinary research). As this research will be on Context Based Learning (CBL), rather than Problem Based Learning (PBL), both introduced in 2.2 Educational Approaches, input from the learners in shaping the learning materials will be minimal and rely on the expertise of the researcher making them. Therefore, the frameworks reviewed in the previous sections that are associated with participation or input from various stakeholders may be less appropriate when applied towards this body of research. Furthermore, as this work is not planned to be implemented on an organisational or enterprise level, large-scale roll-out or system dissemination is unnecessary.

Based upon this, the most appropriate existing framework identified is the TPACK; however, this will need to be modified to incorporate findings from this research, which will act as a foundation for the created learning resource, GIS Lessons for You (Chapter 7). To recap, the TPACK is made up of technological, pedagogical and content knowledge and their intersections, which is illustrated in Figure 6.3 and summarised as follows:

- Pedagogical Knowledge (PK): Learning Approaches
- Content Knowledge (CK): Subject Area Expertise
- Technological Knowledge (TK): Understanding & Application of Technology
- Pedagogical Content Knowledge (PCK): Teaching Subject Area Expertise through Learning Approaches
- Technological Pedagogical Knowledge (TPK): Learning Approaches for Understanding & Application of Technology
- Technological Content Knowledge (TCK): Teaching Subject Area Expertise through Understanding & Application of Technology
- Technological Pedagogical Content Knowledge (TPACK): Teaching Subject Area Expertise and use of Learning Approaches for Understanding & Application of Technology
- Context: Institutional Learning Environment

Mapping the main tenets of this research to these, the following can be said (summarised in red in Figure 6.9):

- PK: Context Based Learning (CBL) (2.3 Learning in Interdisciplinary Research) [Educational Theory]
- CK: Geographic Information Science and Technology Body of Knowledge (GIS&T BoK) (2.4.5 Geographic Information Science and Technology Body of Knowledge)
- TK: Use of GIS (4.2.3 Results; 5.1.3 Results – Interview Questions, 5.2.3 Results)
- PCK: Learning GIS&T BoK through CBL
- TPK: CBL for Use of GIS
- TCK: Teaching GIS&T BoK for Use of GIS
- TPACK: Teaching and Learning GIS&T BoK through CBL for Use of GIS
- Context: Institutional Learning Environment

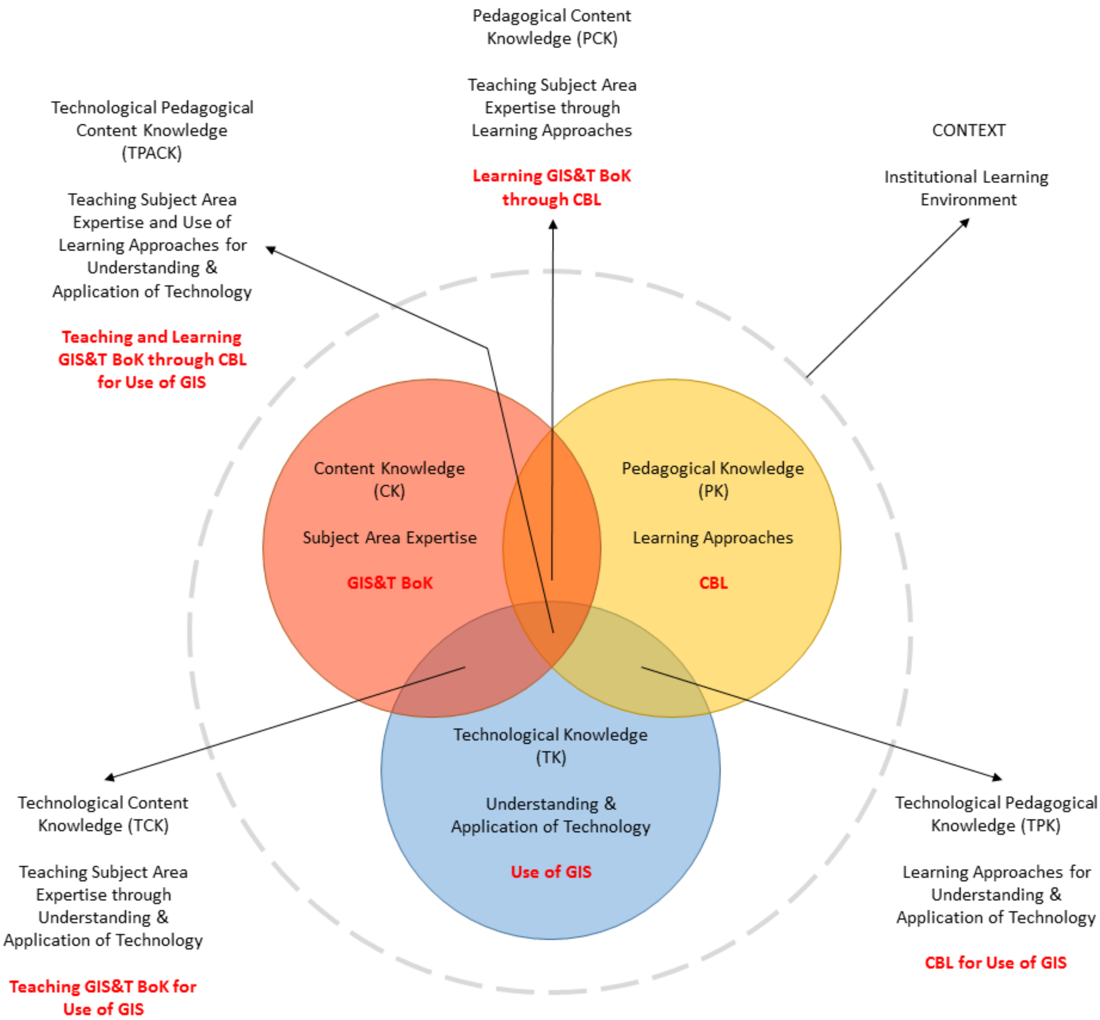


Figure 6.9 TPACK framework with research elements mapped to it

However, outputs of the work so far suggest some additions to the TPACK framework. CBL is a hypothesised learning approach for PK, based on the findings from 2.2 Educational Approaches; however, as detailed in previous sections (4.2 Online Survey, 5.1 One-on-One Interviews, 5.2 Learning Diaries), interdisciplinary researchers learning GIS tend to utilise informal learning approaches (e.g. internet searches, watching a video or asking a more experienced person). Nevertheless, CBL, based on its theoretical ties to informal learning (as identified in Figure 6.1), may still be a conducive learning approach for interdisciplinary researchers. Therefore, it could be suggested that informal approaches may be supported or improved through the addition of more structured, CBL ones, which will be tested in Chapter 7 and Chapter 8.

CBL may offer further enrichments to the suggested framework; its use of context, described as being about the institutional learning environment, should also include the context of the problem domain for the learning activity. These two contexts are the Learning Environment Context and the Learning Activity Context respectively, which relates back to the dual axis of context, as recognised by Rose (2012). The Learning Activity Context affects Content Knowledge (CK), Pedagogical Knowledge (PK) and Technological Knowledge (TK), as it may necessitate changes to any of these elements; however, the Learning Environment Context exists at a higher level, which may affect all elements including the Learning Activity Context.

Incorporating these updates, the amended TPACK framework for Learning GIS in Interdisciplinary Research, Figure 6.10 updates Figure 6.9 and maps to the various tenets and outputs of this research. At its nexus, it suggests Teaching and Learning necessary GIS&T BoK concepts (Analytical Methods, Cartography and Visualization, and Geospatial Data) through CBL that complements informal learning, using relevant Learning Activity Contexts for Use of GIS (e.g. ArcGIS, QGIS, Web GIS), supported by the Learning Environment Context.

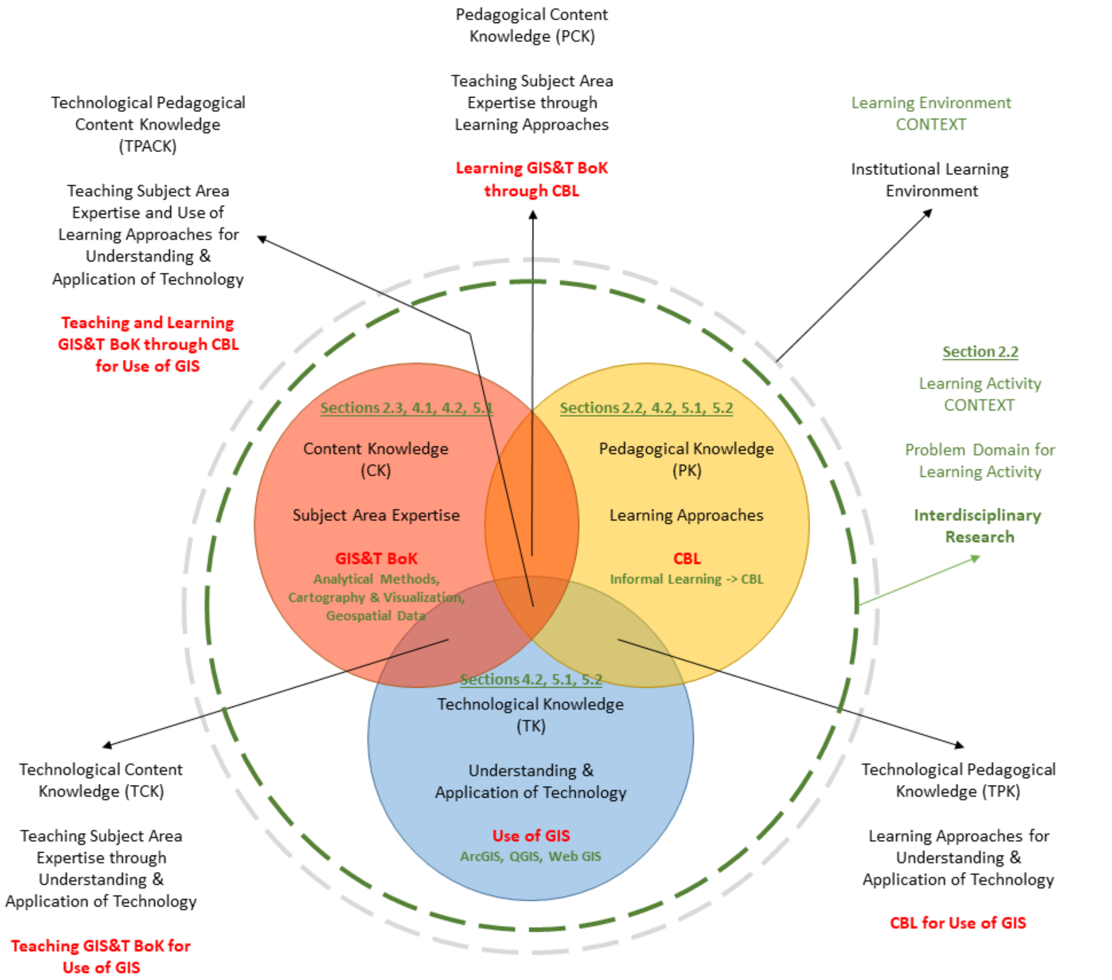


Figure 6.10 Modified TPACK framework for Learning GIS in Interdisciplinary Research

This work can then summarise and set forth the following guidelines to help better support these researchers in learning GIS:

- CONTENT KNOWLEDGE: From the GIS&T BoK, KAs Analytical Methods, Geospatial Data, and Cartography and Visualization seem to contain the topics interdisciplinary researchers seem to be interested in when learning and using GIS (2.4 Geographic Information Systems Education, 4.1 Google Scholar Analysis, 4.2 Online Survey, 5.1 One-on-One Interviews). Therefore, these should be the KAs focused on by learning resources.
- PEDAGOGICAL KNOWLEDGE: In practice, though survey respondents and interviewees used informal approaches, they may use Context Based Learning approaches instead of or in conjunction with these, which may be able to provide more support for interdisciplinary researchers learning GIS (2.2 Educational Approaches, 4.2 Online Survey, 5.1 One-on-One Interviews, 5.2 Learning Diaries).

- TECHNOLOGICAL KNOWLEDGE: Though survey respondents and interviewees used established GIS platforms (e.g. ArcGIS, QGIS), it is worth noting the prominence of web GIS technologies and their easy implementation and deployment in interdisciplinary research projects (4.2 Online Survey, 5.1 One-on-One Interviews, 5.2 Learning Diaries).

This framework and guidelines were used to construct a prototype learning resource that was the foundation for subsequent research for this report. These may also provide guidance for the future construction of learning materials for GIS education and act as inspiration for other educators.

6.5 Discussion

The purpose of the work of this chapter was to investigate frameworks to identify one or aspects of some that may be used to provide structure for further research to be undertaken with regard to building a suitable learning resource for interdisciplinary researchers learning GIS. Based on the outputs from Chapter 4 and Chapter 5, such a framework would need to incorporate an appropriate learning approach (CBL), relevant GIS concepts (Analytical Methods, Cartography and Visualisation, Geospatial Data), for platforms interdisciplinary researchers use (ArcGIS, QGIS, Web GIS). A review of frameworks had shown that relevant ones focused on how to learn, how to manage information and how to integrate GIS. These were then discussed in detail and based on the strengths and weaknesses outlined, the TPACK framework provided a suitable foundation that could be modified for this work. The modified TPACK framework, which suggests at its nexus the focus of Teaching and Learning GIS&T BoK through CBL for Use of GIS, as well as the guidelines presented here have been published in Rickles, Ellul and Haklay (2017). It should be noted that the frameworks reviewed are at least over 5 years old and were selected as they were considered relevant to this research area. This highlights not only that this area is currently under researched, but that the outputs of this report will provide a necessary update and contemporary expansion.

Application of the modified TPACK framework for learning GIS in interdisciplinary research and proposed guidelines may improve the learning experience for interdisciplinary researchers. It is suggested that CBL resources be created that complement or supplement existing informal learning approaches, while being sensitive to the nuances of disciplinary language to minimise misunderstandings. In general, all the different participants in the GIS chain have a role to play in conveying information in an understandable way – from software vendors ensuring that their tools are usable and as jargon-free as possible, to educators by providing introductory courses not only on specialist programmes, but also as part of more general scientific training. If this is carried out in a contextually relevant way that feels familiar to learners from different disciplines, this may help them to focus on the GIS concepts they wish to learn rather than extraneous information.

Moving forward, the proposed framework and guidelines may be used to structure a learning resource for interdisciplinary researchers who wish to learn GIS. Such a resource would need to teach GIS concepts and use of the GIS itself for practical application purposes through relevant learning activities to the learner via an institution able to accommodate said resource. Compiling bespoke or tailor-made learning materials, though, can be time consuming for educators (Juan, 2014), so any system hosting the suggested learning resource should streamline this task as much as possible, in order for it to be a viable solution. To address this, research was undertaken to develop such a learning resource for interdisciplinary researchers, which was titled "GIS Lessons for You" and will be discussed in the following chapter.

Chapter 7 - GIS Lessons for You: Is Context Important?

High quality, bespoke teaching materials for Geographic Information Systems (GIS) can be a valuable resource that educators can use to efficiently teach leaners what they may wish to learn. Coupled with their expertise in delivering lessons and adapting them as necessary for students, GIS educators can use materials and their teaching proficiency to adjust the learning experience as necessary to ensure that learning objectives with GIS are met. This may require educators to be bold and try innovative teaching methods, which they may not be familiar with and so will need to learn them quickly. Some of these efforts may be successful while others might fail. Outside of educators' attempted improvements to their professional practices, though, variables associated with the learners' goals and motivations may introduce further difficulties.

Context Based Learning (CBL), introduced in 2.2 Educational Approaches and discussed in 2.3 Learning in Interdisciplinary Research, may be conducive for learning GIS in IDR and educators could incorporate this into their practice to improve the learning experience. The work of this chapter incorporates CBL and builds on the findings from the previous chapters, which may be summarised as follows:

- Interdisciplinary Challenges: Difficulties Related to Collaborating with Other Disciplines and Time Constraints emerged as the most common challenges encountered in interdisciplinary research (IDR) (2.1 The Current State of Interdisciplinary Research, 4.1 Google Scholar Analysis, 5.1 One-on-One Interviews).
- Interdisciplinary Solutions: Building Relationships with Members of the Group and Provide Training on Technical and Supplemental Skills clearly stand out as the most often suggested solutions to IDR challenges (2.1 The Current State of Interdisciplinary Research, 4.1 Google Scholar Analysis, 5.1 One-on-One Interviews).
- GIS Concepts: Geospatial Data, Analytical Methods and Cartography and Visualization have concepts most relevant to what those engaged in IDR wish to learn (2.4 Geographic Information Systems Education, 4.1 Google Scholar Analysis, 4.2 Online Survey, 5.1 One-on-One Interviews).
- Informal Learning: Those in IDR who have previously learned GIS concepts have largely performed online searches, watched videos and asked for help. One major issue that continues to plague learners is that of understanding specialist terms associated with GIS that may either have conflicting meanings from their own

disciplinary understandings or they may be altogether unaware of them (2.2 Educational Approaches, 4.2 Online Survey, 5.1 One-on-One Interviews, 5.2 Learning Diaries).

CBL suggests that the relevance of the context of the learning activity and environment is important to the process of learning itself and links back to Informal Learning, as outlined in Figure 6.1. Bearing this in mind, with respect to the outcomes from the previous work, the following research question may begin to be addressed (also illustrated in Figure 1.3):

- Can a contextually relevant mixed formal (institutionally led)/non-formal (loosely organised) learning resource improve uptake and application of GIS in IDR?

Considering the previous chapters' findings and using the structure proposed by the modified Technological Pedagogical Content Knowledge (TPACK) framework for learning GIS in IDR as a basis (Figure 6.10), the proposed research question may begin to be investigated with the use of a resource that facilitates Teaching and Learning Geographic Information Science & Technology (GIS&T) Body of Knowledge (BoK) through Context Based Learning (CBL) for Use of GIS with lessons that use a relevant Learning Activity Context (LAC). "GIS Lessons for You" (GL4U) – described in this chapter – was a tool created to test this hypothesis in practice and has been added to the modified TPACK framework (Figure 7.1).

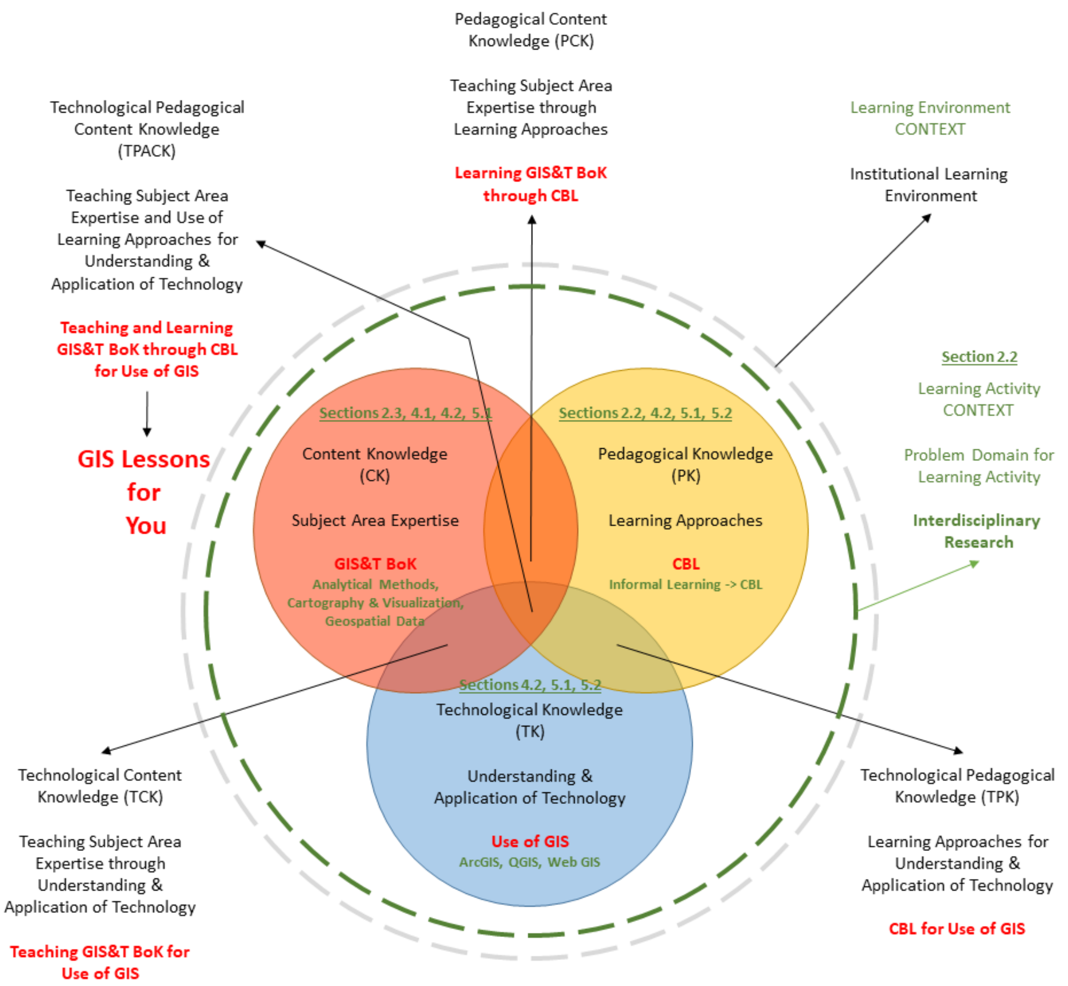


Figure 7.1 Modified TPACK framework for Learning GIS in IDR, including GIS Lessons for You

7.1 Aims for GIS Lessons for You (GL4U)

This resource may help to address the knowledge gap those coming from different disciplines face when learning GIS and may be able to deliver materials in a time efficient manner. This may be able to help establish GIS as a common platform for dialogue with those from different disciplines. Consequently, this may also help build relationships and possibly a community of practice around the technology to foster innovative applications of GIS. To ensure interdisciplinary researchers are focusing on concepts relevant to them, materials within GL4U are on and around creating data, analysing them and producing simple and understandable maps from them. GL4U has been made available online and uses associated keywords to ensure it is discoverable, aligning with how interdisciplinary researchers are already looking for materials. Possible terms researchers used within their home disciplines have been incorporated into the LACs of the lessons and GIS terms have been simplified and explained to try to avoid misunderstandings.

To detail the technology for the system, GL4U was built as an online system to be hosted on a web server and accessed publically via the internet. This was to ensure that learners had access to materials, rather than using printed copies or having to share locally stored static files. Furthermore, as per the findings from previous chapters (4.2 Online Survey, 5.1 One-on-One Interviews, 5.2 Learning Diaries), interdisciplinary researchers are looking for learning materials online, so they should be shared that way. Whichever online medium was to be used, it would have to be cost effective, provide an understandable user interface with upgradeable components to keep up to date with technology changes and allow content to be easily managed and updated. It would also need to provide the ability to switch key text and images based on the context for the lesson, easy movement between steps in the lesson and general system management (e.g. spam filter, contact form, analytics).

Some possibilities initially investigated were WordPress.com, the WordPress platform and bespoke coded web pages. WordPress.com could be used for its pre-existing website templates to avoid creating pages and hosting them. WordPress also has a source code platform that can be downloaded and implemented on a designated web server, which can be altered for custom use. Bespoke coded web pages and layouts could also be created and administrated from a customised webserver. Considering the functional requirements of the platform needed to create GL4U, listed in Table 7.1, these were reviewed with respect to WordPress.com, the WordPress platform and bespoke coded pages. Though WordPress.com did allow pages to be quickly created, it did not provide the ability to customise back-end scripts to accommodate custom functionality. Bespoke coded web pages, though considered, were not an ideal solution, as functions from code libraries may be deprecated and image and link references might break, which could require ongoing maintenance and take time away from content creation. Ultimately, GL4U was created using the WordPress platform, but hosted as a website on a private server, as this was procured at a discounted rate of £60 per year. This would provide the means for content creation and management as well as allow custom configuration or creation of any necessary components. The WordPress platform was also selected as it is considered to be secure, reliable and adaptable (Friedman, 2012) and could be implemented within the available timeframe for the work, as the researcher was already familiar with the necessary architecture and associated technologies (MySQL, PHP). WordPress also offered a variety of plugins that could deliver necessary aspects of the system, and so the plugins listed in

Table 7.2 Functional Requirements, WordPress Plugins and their Descriptions

were utilised/created to meet the functional requirements of the research and/or system.

Table 7.1 Functional Requirements for GL4U and comparison of WordPress.com, WordPress Platform and Bespoke Coded Web Pages

Functional Requirement	WordPress.com	WordPress Platform	Bespoke Coded Web Pages
The system will allow the ability to create lessons based on different learning activity contexts	Lessons and contexts could have been constructed using functionality of the system with work arounds	Lessons and contexts could have been constructed extending functionality of the system	Regardless of development environment, this would require custom development, which may take time
The system will allow key text and image variables to be stored so they may be updated in the lessons depending on lesson context	Functionality did not exist and it was not possible to extend the basic implementation	Possible with the Advanced Custom Fields plugin	Regardless of development environment, this would require custom development, which may take time
The system will allow learners to move between steps easily	Functionality did not exist and it was not possible to extend the basic implementation	Possible with the Advanced Post Pagination plugin	Could be controlled through style variables and existing language libraries; custom controls would require development
The system will allow easy handling of any spam comments received	Functionality exists	Possible with a few plugins (e.g. Akismet)	Functionality would need to be set up and implemented on the server side
The system will have a form that users can use to contact the administrator with any requests	Functionality exists	Possible with Contact Form 7 plugin	Could be controlled through existing language libraries; custom controls would require development
The system will provide a means to use Google Analytics for tracking web traffic	Functionality exists	Possible with Google Analytics by MonsterInsights plugin	Google Analytics tracker can be set in the header of the page
The system shall have a component that designates the lesson and lesson context in order to update key text and image variables	Functionality did not exist and it was not possible to extend the basic implementation	No existing plugin; custom one would need to be developed	Could be controlled through style variables and existing language libraries; custom controls would require development

Table 7.2 Functional Requirements, WordPress Plugins and their Descriptions

Functional Requirement	System / Research Requirements	WordPress Platform Functionality	Description
The system will allow the ability to create lessons based on different learning activity contexts	System – necessary to provide the ability to rapidly change the context and lessons to support experiments in Chapter 7 and Chapter 8. Research – This facilitates concepts of CBL to be explored as hypothesised in 2.3 Learning in Interdisciplinary Research	Use of posts, tags and categories	Using the functionality in the platform, contexts will be set as categories, lessons will be set as tags and individual contexts' lessons will be saved as posts. A custom developed plugin, the Post by Category and Tag Widget plugin, will be used to switch between lessons and contexts in the system.
The system will allow key text and image variables to be stored so they may be updated in the lessons depending on lesson context	System – necessary to provide the ability to rapidly change the context to support experiments in Chapter 7 and Chapter 8. Research – This facilitates concepts of CBL to be explored as hypothesised in 2.3 Learning in Interdisciplinary Research	Advanced Custom Fields plugin	This plugin was key to GL4U; using shortcodes, it is possible to swap variables in and out of blog posts/pages, as designated by the created shortcode template. Each context has its own shortcode template, with localised variables established within the lessons that are used for switching text and screenshots as necessary.
The system will allow learners to move between steps easily	System – allows lesson materials to be presented in smaller portions Research – smaller material portions can improve constructivist scaffolding of complex GIS learning materials (2.2.1 General Education Theories)	Advanced Post Pagination plugin	This was used to paginate individual posts so as to create the individual steps for each of the lessons

The system will allow easy handling of any spam comments received	System – as commenting was made available, bots/vendors would submit irrelevant comments with links, which need to be removed Research – This would allow online learners to interact with each other in a social constructivist manner (2.2.1 General Education Theories)	Akismet plugin	Spam filter
The system will have a form that users can use to contact the administrator with any requests	System – Feedback could be used to improve functionality of the resource Research – Requests for contexts could be used to create new ones for expanded CBL opportunities (2.3 Learning in Interdisciplinary Research)	Contact Form 7 plugin	Allows users to submit a form for feedback on GL4U or to request a new context to be created
The system will provide a means to use Google Analytics for tracking web traffic	System – this would allow usage to be tracked and monitored over time	Google Analytics by MonsterInsights plugin	Plugin for logging visitors to the site for reporting purposes
The system shall have a component that designates the lesson and lesson context in order to update key text and image variables	Research – This was to switch between the lessons and contexts to facilitate CBL with the resource (2.3 Learning in Interdisciplinary Research)	Post by Category and Tag Widget plugin (custom developed)	This is a custom created plugin that displays a post with a designated Category and Tag. For GL4U, Category relates to Context and Tag relates to Lesson, so if a user selects “Medieval Swansea” as the Context (Category) and “4. Creating a Presentation” as the Lesson (Tag), the corresponding post will be displayed after clicking the button “Go To Lesson”. (Note: This assumes a one-to-one relationship between Category and Tag)

GIS platforms that were considered for the platform that would be taught in the lessons included ArcGIS for Desktop (ArcGIS, 2016), QGIS (QGIS, 2016) and web GIS platforms such as Community Maps (Community Maps, 2016), CARTO (CartoDB, 2016) and ArcGIS Online (ArcGIS Online, 2018). ArcGIS for Desktop would require users to be appropriately licenced to use the software or to have access to machines that were licenced; as this might limit user participation, this platform was not used. Though QGIS is a free, open source platform, users would still need to install and configure the software on their machines, which may prove difficult for some. Community Maps, an online platform that was created by researchers at UCL, was accessible via a web browser, but functionality was limited, the support community for it was small and anything needed by this research would need to be developed, which would affect projected delivery timeframes. CARTO is a more developed web GIS platform; however, its functionality available to demo accounts was limited and licenced accounts were not readily available.

In the end, ArcGIS Online was the GIS that was selected to be the platform used for the lessons in GL4U. This platform takes into account not only the popularity of ArcGIS software and web GIS, as identified by the Online Survey (4.2 Online Survey) and the One-to-One Interviews (5.1 One-on-One Interviews), but also capitalises on the ease of deployment of ArcGIS Online. Users are able to sign up for free ArcGIS Online accounts, without any organisation affiliation, that immediately have access to basic functionality and 2 GB storage space; therefore, if any learners were not part of the organisational account, they would still be able to use the GIS to create, investigate and visualise information. Organisational accounts were also able to be created for users, should there be interest to use more advanced functionality in ArcGIS Online as part of GL4U, as UCL had procured credits to use the system and the researcher was an administrator for it. As ArcGIS Online is a web platform, users only need access to the internet and web browser to use it – meaning there is no need to install and configure specialist software. A comparison between all the evaluated GIS platforms has been listed in Table 7.3.

Table 7.3 Functional Requirements and Evaluated GIS Platform Capabilities

Functional Requirements	ArcGIS For Desktop	QGIS	Community Maps	CARTO	ArcGIS Online
No Licencing Required for Basic Use	No	Yes	Negotiable	Negotiable	Yes
No Installation or Configuration	No	No	Yes	Yes	Yes
May Require Development Work	No	No	Yes	No	No
Community for Software Support	Yes	Yes	No	Yes	Yes
Existing Licence Agreement for Advanced Use	Yes	N/A	N/A	No	Yes

The ArcGIS Online lessons were constructed to familiarise learners with the platform's various capabilities and begin to introduce them to concepts from GIS&T BoK KAs that were identified as relevant to interdisciplinary researchers. These were identified from previous research as Analytical Methods, Cartography and Visualization and Geospatial Data (2.4 Geographic Information Systems Education, 4.1 Google Scholar Analysis, 4.2 Online Survey, 5.1 One-on-One Interviews). Table 7.4 shows how each of the lessons map to ArcGIS Online capabilities to be taught, its steps and their purpose – whether it was to teach learners how to use the software or which KAs they relate to from the GIS&T BoK. The initial teaching materials used to construct the lessons were created for face-to-face teaching with the DPU in 2014 (detailed in 3.3 Development Planning Unit (DPU)) and then updated for GL4U. These were used for the initial context on "Water Access in Lima", which will be described in greater detail in 7.2 Interdisciplinary Learning Opportunities for GL4U, and were the template for the other contexts. The text and images from the lessons were reviewed to see what would need to change within them so they may be adapted for different contexts. The text and images that needed to change were set up in the lesson text as Advanced Custom Fields shortcodes (e.g. [acf field="location"] for Location) and the fields were populated with the context variable values to ensure they correctly showed up within the lesson (e.g. Location for the context “Water Access in Lima”, the value would be “Lima”.

As the LAC for the lessons was to play a vital role to investigate the research question, further contexts were created based on existing and potential upcoming teaching experiences. These were for continued work with the DPU as well as new teaching opportunities with students from UCL Digital Humanities and interdisciplinary researchers on the Challenging RISK (Resilience by Integrating Societal and Technical Knowledge) project, which will be described in the following section.

Table 7.4 ArcGIS Online Capabilities and GIS&T BoK KAs mapped to GL4U Lessons

ArcGIS Online Capabilities	Lessons	Descriptions	Lesson Steps	Purpose
Provide basic understanding of ArcGIS Online site structure	"1. Intro to ArcGIS Online"	This is a basic lesson to familiarise users with ArcGIS Online as a platform. In it, the map, content storage system and account settings are explored so that users may adjust any aspects as they see fit.	1. The Main Pages of ArcGIS Online	Software Use
			2. Sign In Page	Software Use
			3. Create Account Page	Software Use
			4. Main Page	Software Use
			5. Features Page	Software Use
			6. Plans Page	Software Use
			7. Help Page	Software Use
			8. Gallery Page	Cartography and Visualization
			9. Groups Page	Software Use
			10. My Content Page	Software Use
			11. My Map Page and Elements	Cartography and Visualization
			12. Details Option	Cartography and Visualization
			13. Add Layers Option	Geospatial Data
			14. Basemap Option	Cartography and Visualization; Geospatial Data
			15. Save Map Option	Software Use
			16. Share Map Option	Software Use
			17. Print Map Option	Cartography and Visualization
			18. Measure Tool	Analytical Methods

			19. Bookmarks Tool	Software Use
			20. Search Tool	Analytical Methods
			21. New Map Option	Software Use
			22. Account Options	Software Use
			23. Overview Map Option	Cartography and Visualization
			24. End of Lesson	Software Use
Basic navigation around the map (e.g. pan, zoom in/out, etc.) Add layers of information from ArcGIS Online, a file (e.g. zipped up shapefile [includes the .shp, .shx, .dbf and .prj files]), a remote web resource (e.g. KML file) or a Map Notes layer (to make annotations on the map)	“2. Adding and Displaying Layers of Information”	In this lesson, users learn how to add layers from different sources and change the colour of features in a way so they may better highlight the information they are displaying (e.g. blue for rivers, grey for roads, etc.).	1. Zoom to Area	Cartography and Visualization; Analytical Methods
			2. Search for Layers to Add from ArcGIS Online	Geospatial Data
			3. Types of Layers	Software Use
			4. Item Details Page	Software Use
			5. Add Layer from File	Geospatial Data; Cartography and Visualization
			6. Add Layer from Web	Geospatial Data; Cartography and Visualization
			7. Add Map Note Layer	Geospatial Data
			8. Add Map Note	Geospatial Data; Analytical Methods; Cartography and Visualization
			9. Contents Panel	Software Use
			10. Change Style	Cartography and Visualization
			11. End of Lesson	Geospatial Data; Cartography and Visualization
Ability to change the basemap Save the map and give it appropriate metadata (e.g. title, tags, summary)	“3. Saving and Printing a Map”	Users learn to save and print the map that they created in the previous lesson, including how to change the basemap to better display the information in the layers they have added to the map.	1. Saving Your Map	Software Use
			2. Your Saved Map	Software Use
			3. Your Saved Web Map	Software Use

			4. Changing the Basemap	Cartography and Visualization
			5. Printing Your Map	Cartography and Visualization
			6. End of Lesson	Cartography and Visualization
Create a presentation from a map	"4. Creating a Presentation"	ArcGIS Online allows users to construct a presentation of set extents/areas of the map, to create a narrative with the information in the map; this lesson shows users how to make use of this functionality.	1. Creating a Presentation	Software Use
			2. Access the Web Map	Software Use
			3. Create the Presentation	Software Use
			4. Create Your First Slide	Cartography and Visualization
			5. Create a Second Slide	Cartography and Visualization
			6. Create a Third Slide	Cartography and Visualization
			7. Finish the Presentation	Software Use
			8. Accessing the Presentation	Software Use
			9. End of Lesson	Software Use
Share the map with the public Create an ArcGIS Online web application known as a Story Map, which is a digital map that combines hypermedia narrative information (e.g. text, photos, videos, etc.)	"5. Sharing Your Content through Story Maps"	ArcGIS Online's Story Maps are templates that may be used that not only showcase a map, or series of maps, but provides accompanying text, images and videos to provide a discrete narrative, while also allowing the map or maps to be explored in greater detail, should the user be interested to do so. This lesson demonstrates how to take the map that was previously created, build a narrative around it and share it out so others may investigate the given information.	1. Share Your Web Map	Software Use
			2. Make a Web Application	Cartography and Visualization
			3. Selecting a Template	Cartography and Visualization
			4. Select a Story Maps Template	Software Use
			5. Configuring Your Story Map	Cartography and Visualization; Geospatial Data
			6. Review your Story Map	Cartography and Visualization
			7. End of Lesson	Software Use

7.2 Interdisciplinary Learning Opportunities for GL4U

UCL Centre for Digital Humanities, founded in 2010, is a cross-faculty research centre that brings together researchers from a wide range of disciplines, with concentrations in computing science, information studies and arts and humanities. Programmes offered range from research-led MA/MSc to PhD projects in a number of areas. Work undertaken for teaching GIS was with a course offered as part of Digital Humanities, coordinated by the UCL School of European Languages, Culture and Society (SELCS), titled “Introduction to Digital Humanities”. This course acts as an introduction to digital tools that SELCS students could use to explore humanities topics of relevance to their discipline, such as mapping out global dispersion of European authors, geographically exploring literature narratives or global dispersion of cultural influences (e.g. music, fashion, the arts, etc.).

The DPU, as previously described (3.3 Development Planning Unit (DPU)), is located in the Bartlett School of Graduate Studies at UCL and brings together researchers from many disciplines such as Political Science, Urban Planning and Sociology to name a few. Programmes offered focus on graduate and postgraduate research in areas such as gender policy and planning, the environment, and social development. Teaching applicable to this research was delivered as part of the Masters in Environment and Sustainable Development on the course “Environment and Sustainable Development in Practice”. This class creates an opportunity for students to be exposed to a set of real-life planned interventions in the field of urban and regional environmental planning and management and, as such, uses GIS in a practical way as one of a number of tools to help analyse and better understand the effect of locational factors in planning.

Challenging RISK is an interdisciplinary research project, started in 2013 and finishing in 2018, that is investigating a variety of approaches to positively impact people’s preparedness for earthquakes and household fires across socio-cultural boundaries. The project brought together researchers from Structural Engineering, Social Psychology and Geographic Information Science. These researchers would be using GIS to compile and analyse spatial data for selecting areas of engagement, recording information around preparedness and sharing with people available resources in the area. As such, it was initially envisaged that team members from the different disciplines would engage with cross-disciplinary analyses and collaborations, so it was hoped that GL4U would act as a resource for teaching GIS.

The concept for the design of GL4U was for it to begin as a learning resource for the interdisciplinary researchers in Digital Humanities, the DPU and Challenging RISK, as the initial contexts were created for them. However, it was hoped that others who came across this online resource who were interested in contextually relevant lessons and engaged in active IDR projects could either use the initial contexts or request new ones to be created for them. Originally, this research was to investigate the nature of and comparisons between online and face-to-face learning; however, even with advertising the capabilities of GL4U, no one came forward to request any custom created contexts. Furthermore, researchers on Challenging RISK no longer needed to learn GIS, as work streams were separated and research became more multidisciplinary rather than interdisciplinary. That meant for this project the Geographic Information Scientists (GIScientists), already familiar with GIS, used GIS for their own purposes and those from the other disciplines used their own discipline specific tools and did not need to learn and use GIS. Nevertheless, the educational concepts from GL4U were incorporated into the learning materials created for participants in Seattle for the tool that was used: Esri's Survey123 (Survey123 for ArcGIS, 2018). This work and these materials were then used to create a Learn ArcGIS lesson, which was jointly created by the researcher and Esri, that serves as an international example of deploying geospatial tools as part of a Citizen Science project (Get Started with Survey123 in ArcGIS, 2018).

Regardless, because of these difficulties in uptake, it was then determined that GL4U would simply be employed as a face-to-face teaching resource. This would be used with the two remaining groups of interdisciplinary students (DPU and Digital Humanities) as they could act as a proxy for interdisciplinary researchers on active IDR projects, investigating the role of context of learning activities and formal/non-formal learning approaches. The contexts for these groups would therefore need to be created for the lessons in GL4U.

7.3 Creating a Context and Lessons in GL4U

In order to create a context in GL4U, the story for the context must first be conceived and necessary datasets gathered. Each story must first be considered for its relevance to the intended learner to ensure that the LAC is aligned to them. With an idea of the story in mind, available datasets can be sought out that would be applicable to the story; however, based upon what may be available, the story may need to be adapted. To utilise the designated functionalities of ArcGIS Online, the datasets need to be in particular file formats (if they are not already) and information constructed and provided for entry into the system, which is as follows:

- A dataset must be uploaded to ArcGIS Online and shared so it is available for the learner to search for it and add it to the map [Search for Layers in ArcGIS Online].
- Two datasets, one polyline and one polygon dataset, must be formatted as zipped up shapefiles and made available for download [Add Layer from File].
- A dataset must be formatted as a Keyhole Markup Language (KML) file and made available for access via a public URL [Add Layer from Web].
- Information for a Name, Description and Image URL / Image Link URL for a point must be provided [Map Notes Point].
- A Title, at least one Tag and a Summary must be given [Saved Map].
- For the creation of the final Story Map, a Title and a Tab Title must be given; to also highlight the functionalities of the narrative that can accompany the map, an Image URL, Image Caption and Description should be given for the Story Map.

With that information for the new context compiled, one must go through the steps for each of the lessons using an existing context in GL4U in ArcGIS Online and create the necessary screenshots for the steps with the new data. Those must be saved, along with noting the new context's values for the variables (which are in bold text) in the lessons, for later access when the lessons for the new context are created.

To create the new context in WordPress, GL4U uses some of its main features and the plugins described in Table 7.2. WordPress is a free and open-source Content Management System (CMS) based on PHP and MySQL that is used by over 30% of all sites across the web (WordPress, 2018). With it, users can create, edit and manage posts through the administrative dashboard to quickly publish content to their website's pages. Outside of content, posts can have categories and tags associated with them so they may be used as filtration dimensions for accessing specific ones. Those accessing the page can also comment on posts to ask questions and provide their thoughts and feedback, if that functionality is enabled. Plugins can also be developed for WordPress to extend its functionalities and can be made available to the WordPress community for others to use. For GL4U, the lessons are created as posts with specific categories and tags assigned to them to designate context and lesson number, respectively. Inside of these, using the Advanced Post Pagination plugin, shortcode is used to designate where lesson text should be divided into sub-pages, which are the steps of the lessons, so content may be more easily digested.

Advanced Custom Fields is one of the key plugins for GL4U. The way this works is that a field group of variables can be created in this plugin that can be set and referenced inside of a post by an associated ID. Each variable has the following values that must be set that are relevant to GL4U:

- Field Label: Label used to display the field in the Advanced Custom Fields interface at the bottom of the post
- Field Name: ID used to store and access created variables
- Field Type: Type of field for the variable (only Text and Image used)
- Required: Designates whether the variable is required to have a value for the post or not
- Default Value (Text only): Default text to be displayed in the field, which may be changed or updated inside of the post, if necessary
- Return Value (Images only): The value to be returned by the referenced object via the shortcode, which could be the Image Object, Image URL or Image ID

The variables to be used by all field groups were derived from the initially created lessons by evaluating them and determining where text and screenshots may need to change to show context specific information. This included references to place names, descriptive sentences and ArcGIS Online interface screenshots that showed how the map looked with context specific information displayed. In total, this resulted in 101 variables across all five lessons that would be used by all contexts. It is worth noting that not all variables are used by each lesson, so default values were set, where possible, so they would not need to be assigned during post creation and only variables used by that lesson would need to be set and others could be ignored. With regard to which field group's variables are accessible to the post, this can be set based on a custom rule; for GL4U the ones that are accessible is determined by the category chosen for the post as the category variables have been used to designate the context to use for the lessons. The use of category for context has further been extended to be used by the Post by Category and Tag Widget, which has been custom created for GL4U. This plugin uses the available categories and tags to populate the context and lessons drop down respectively on the home page of GL4U.

Using WordPress posts, categories, tags and the aforementioned plugins, a new context and lessons for it can be created. To begin, a new field group needs to be created inside the Advanced Custom Fields plugin for the new context; the interface for all context field groups can be seen in Figure 7.2 and one of the fields for an existing context in Figure 7.3. Ideally, one of the existing field groups should be copied, with the fields' default values updated for the new context; however, the free version of this plugin, at the time of creation of this resource, did not have that functionality available, so a new field group needed to be created manually, replicating each of the necessary 101 fields (listed in A.5.2 Advanced Custom Fields – Custom Fields and Values for Each Context). This includes values for Field Label, Field Name and Field Type (an example shown in Figure 7.4) and for images, the Return Value must be set to Image URL (Figure 7.5). Though all fields are identical between contexts, a new field group must be created for each context to avoid conflicts and confusion over default and assigned values between contexts within the system.

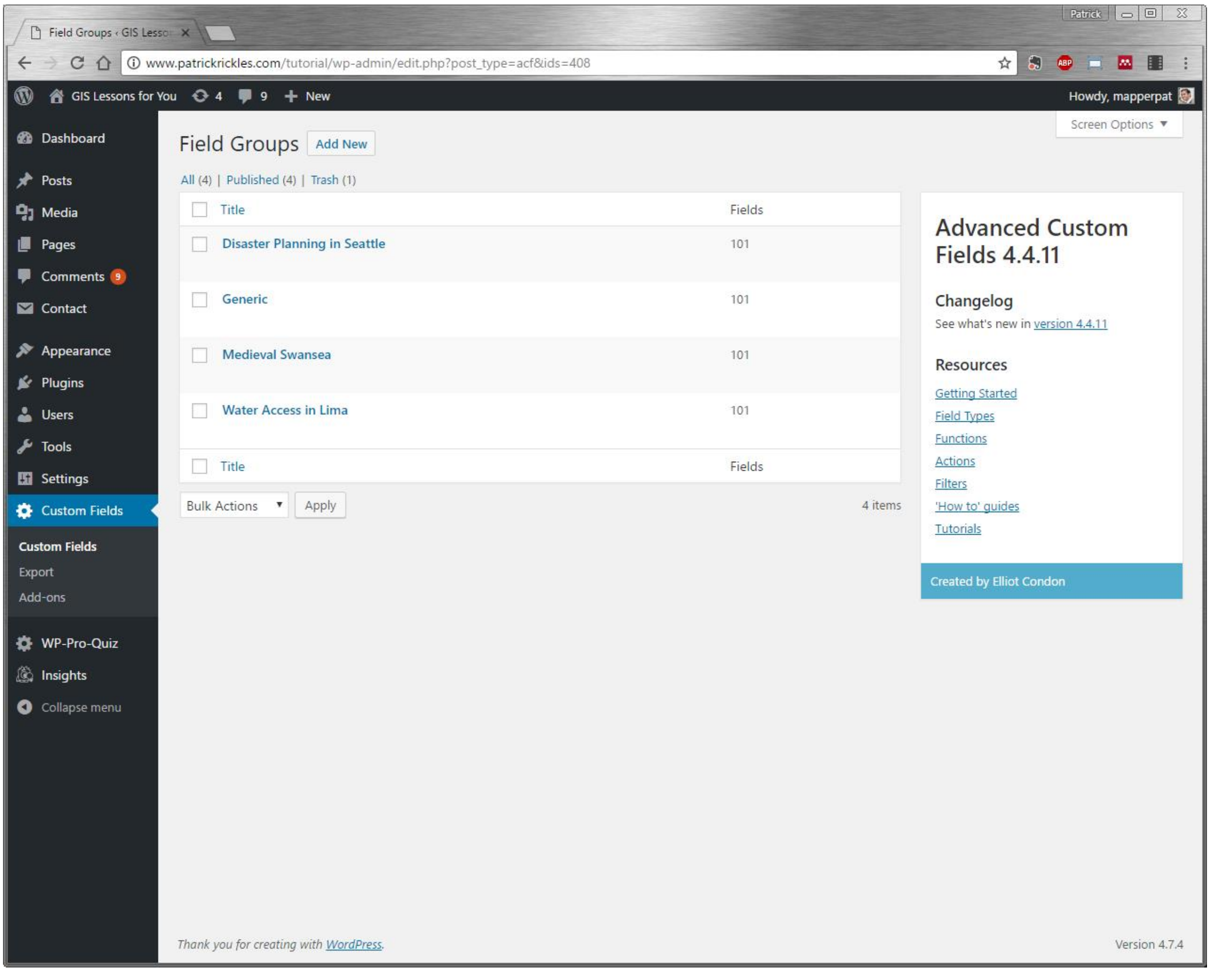


Figure 7.2 Screenshot of the Advanced Custom Fields plugin

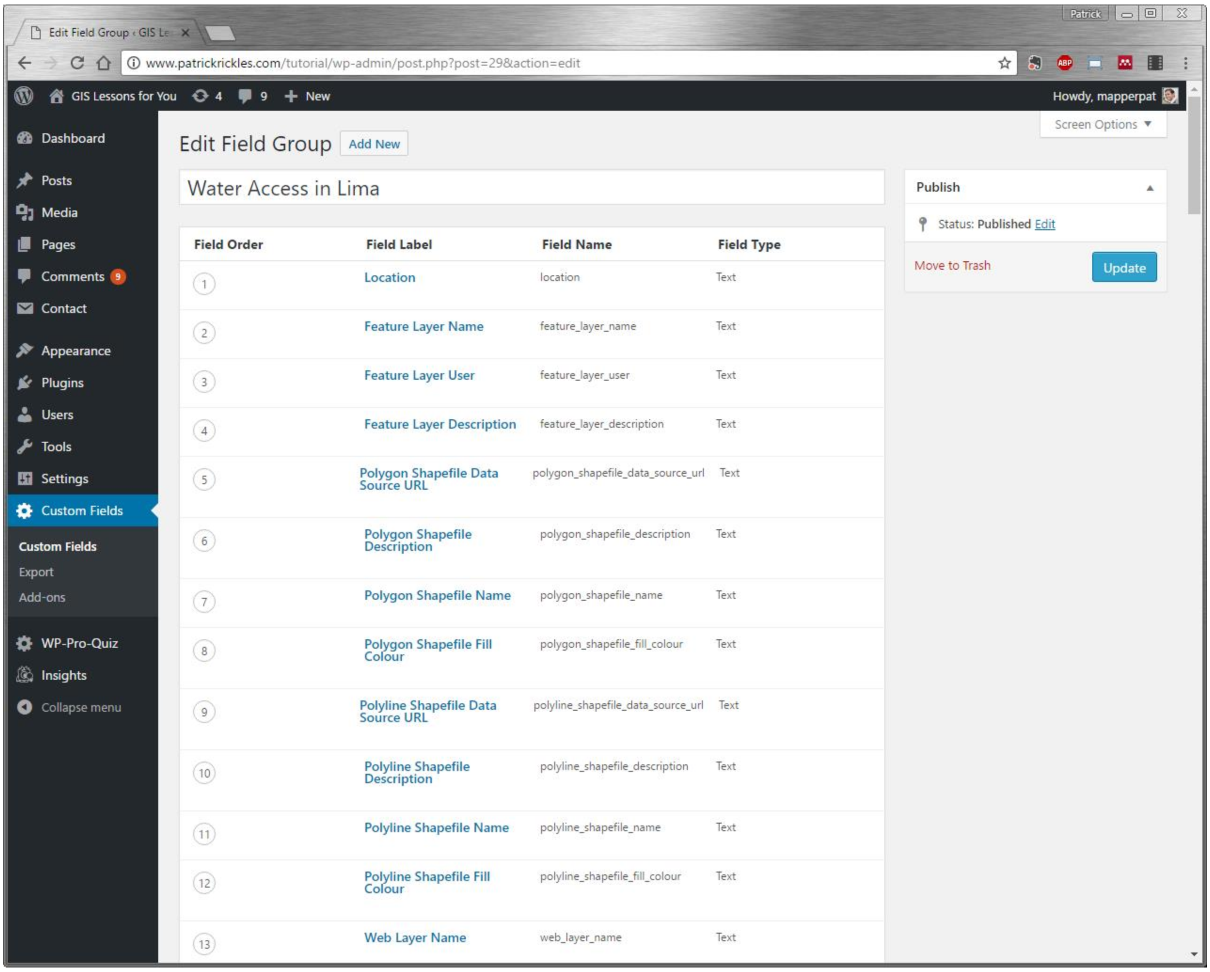


Figure 7.3 *Screenshot of fields from Field Group "Water Access in Lima" in Advanced Custom Fields plugin*

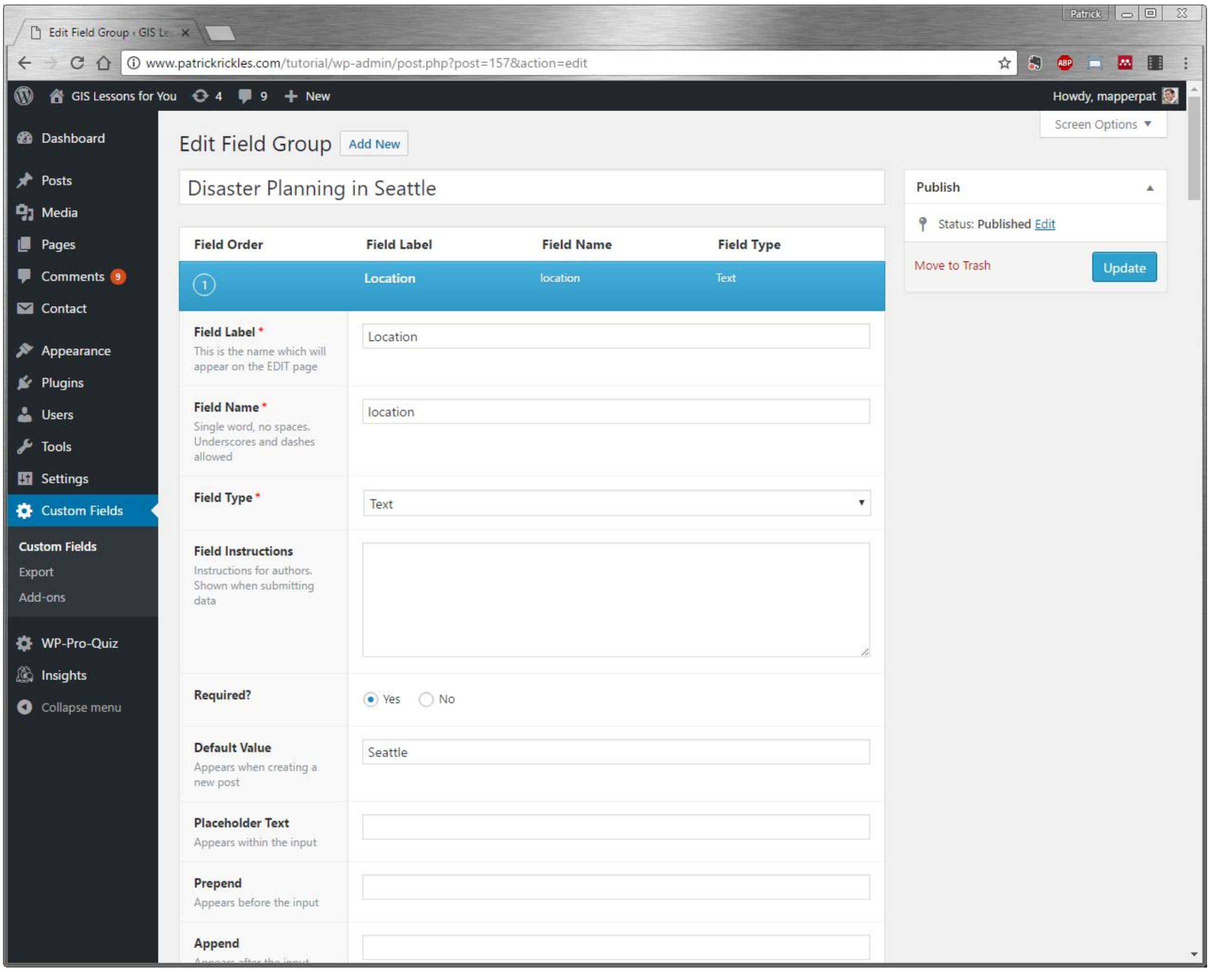


Figure 7.4 *Screenshot of settings for a text field from Field Group "Disaster Planning in Seattle" in Advanced Custom Fields plugin*

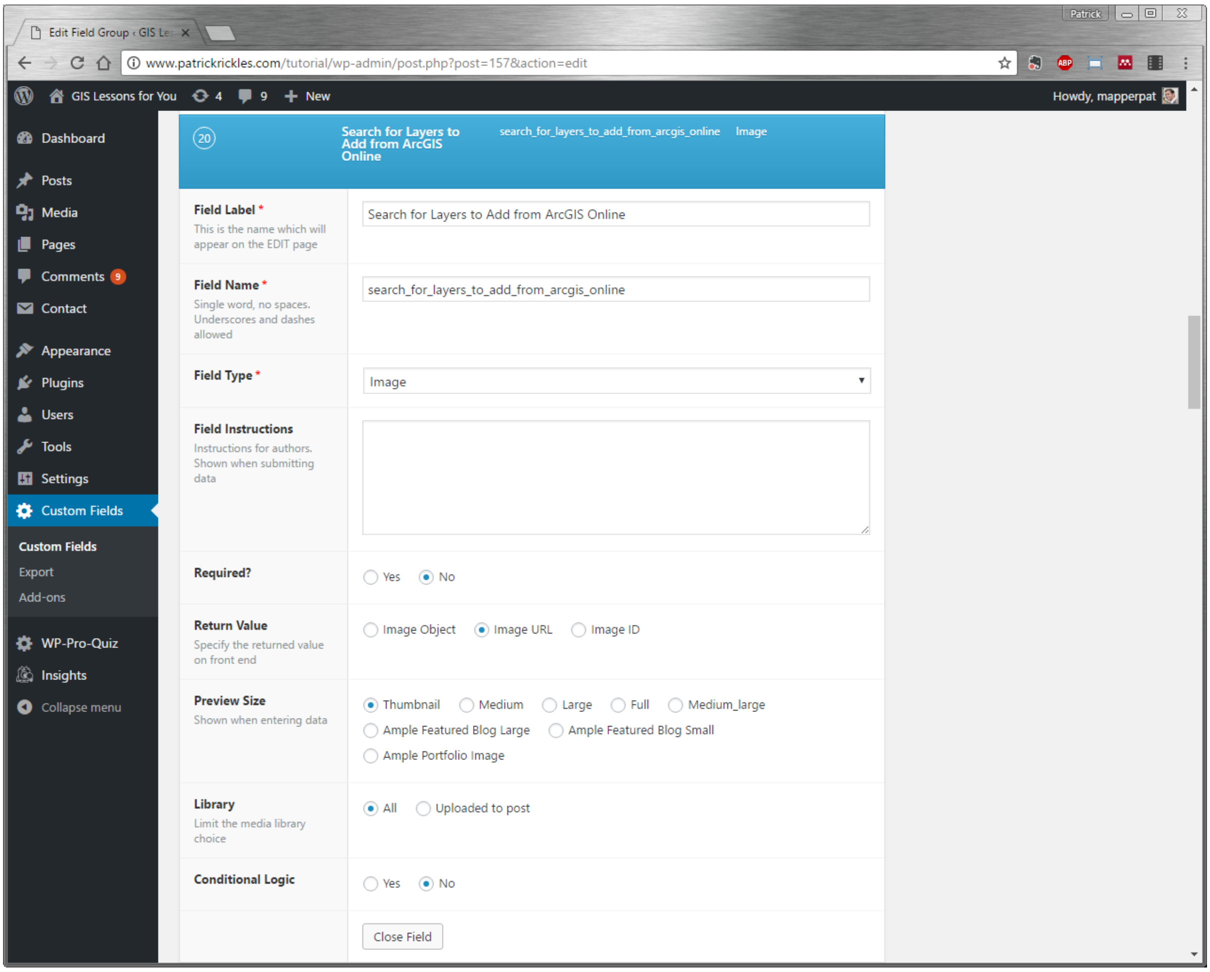


Figure 7.5 *Screenshot of settings for an image field from Field Group "Disaster Planning in Seattle" in* Advanced Custom Fields plugin

With the field group and its variables created, the text from an existing first lesson post (e.g. 1. Intro to ArcGIS Online: Water Access in Lima) must be copied, a new post created (e.g. Intro to ArcGIS Online:<new context>) and the copied text must be pasted into the new post. The format for post names for contexts and their lessons is <lesson name>:<context name>, for the sake of uniformity and the ability to be easily identified within the WordPress dashboard. Next, so that the lesson and context can be accessed via the Post by Category and Tag Widget, which makes them accessible on the Home page of GL4U, the Category and Tag must be set for the post. This can be set in the Category and Tag panels to the left of the post (Figure 7.6); the category corresponds to the context (e.g. Water Access in Lima) and the Tag to the lesson (e.g. 1. Intro to ArcGIS Online). If the context is being created for the first time, the Category representing the context will need to be added using the Add New Category link in the Category panel of the post or under the Categories menu option in the main WordPress Dashboard. It is important to note that Categories and Tags are case sensitive and must be exact; therefore, when creating lessons for a new context, it may be suggested that the

Category or Tag is selected from the drop down or listed selections under Categories or Tags rather than manually entered.

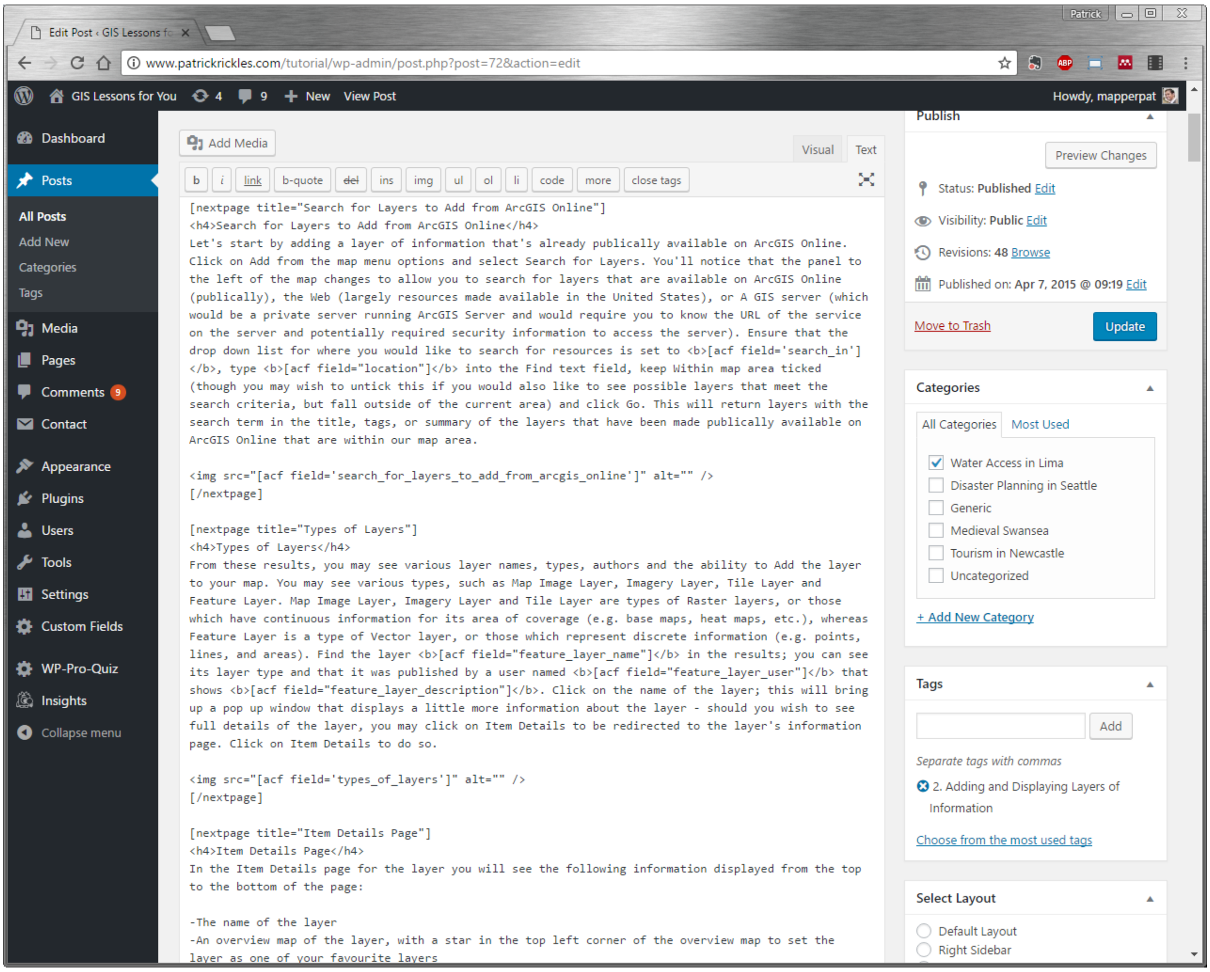


Figure 7.6 Screenshot of post with lesson template text, including shortcodes for Advanced Custom Fields plugin, and necessary Categories and Tags information

Once the title, Category (context) and Tag (lesson) have been set, the custom fields that are below the text of the post must be populated for any/all fields that are in the post (an example of which can be seen in Figure 7.7).

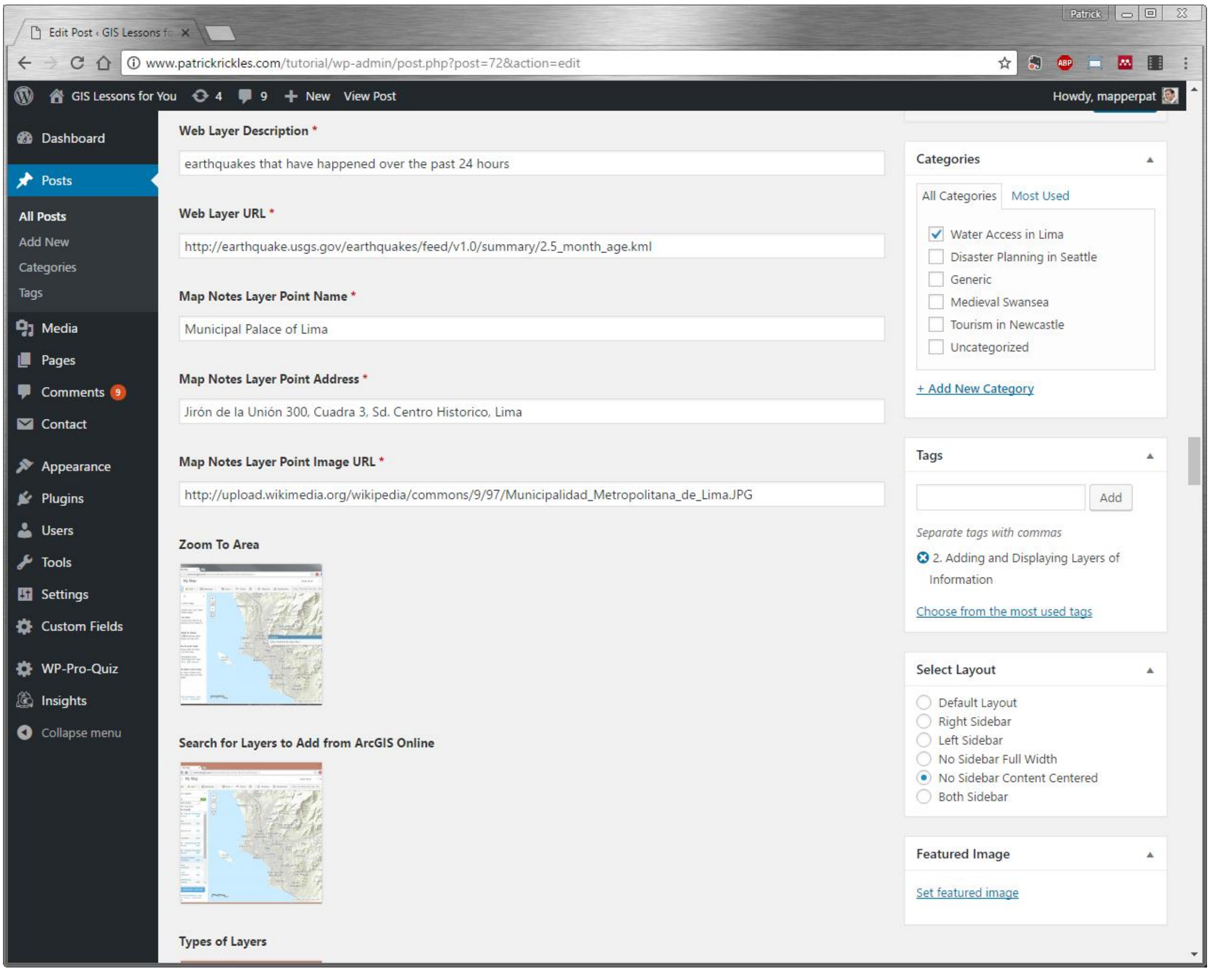


Figure 7.7 *Screenshot of lesson post's fields, populated with necessary Field Group informatio*n (text and images)

To note, this area will show all 101 fields from the Field Group, but again, the post does not use all of them. Only values for the fields that are used in the post will need to be set and default values have been assigned for the fields of the Field Group within Advanced Custom Fields, where possible, to aid in context lesson creation. Once the post has been saved, the context and lesson will then be available via the Homepage of GL4U. This same process for the lesson post must be completed for all five lessons (Intro to ArcGIS Online, Adding and Displaying Layers of Information, Saving and Printing a Map, Creating a Presentation, Sharing Your Content through Story Maps). To summarise, Figure 7.8 illustrates the entire context creation process.

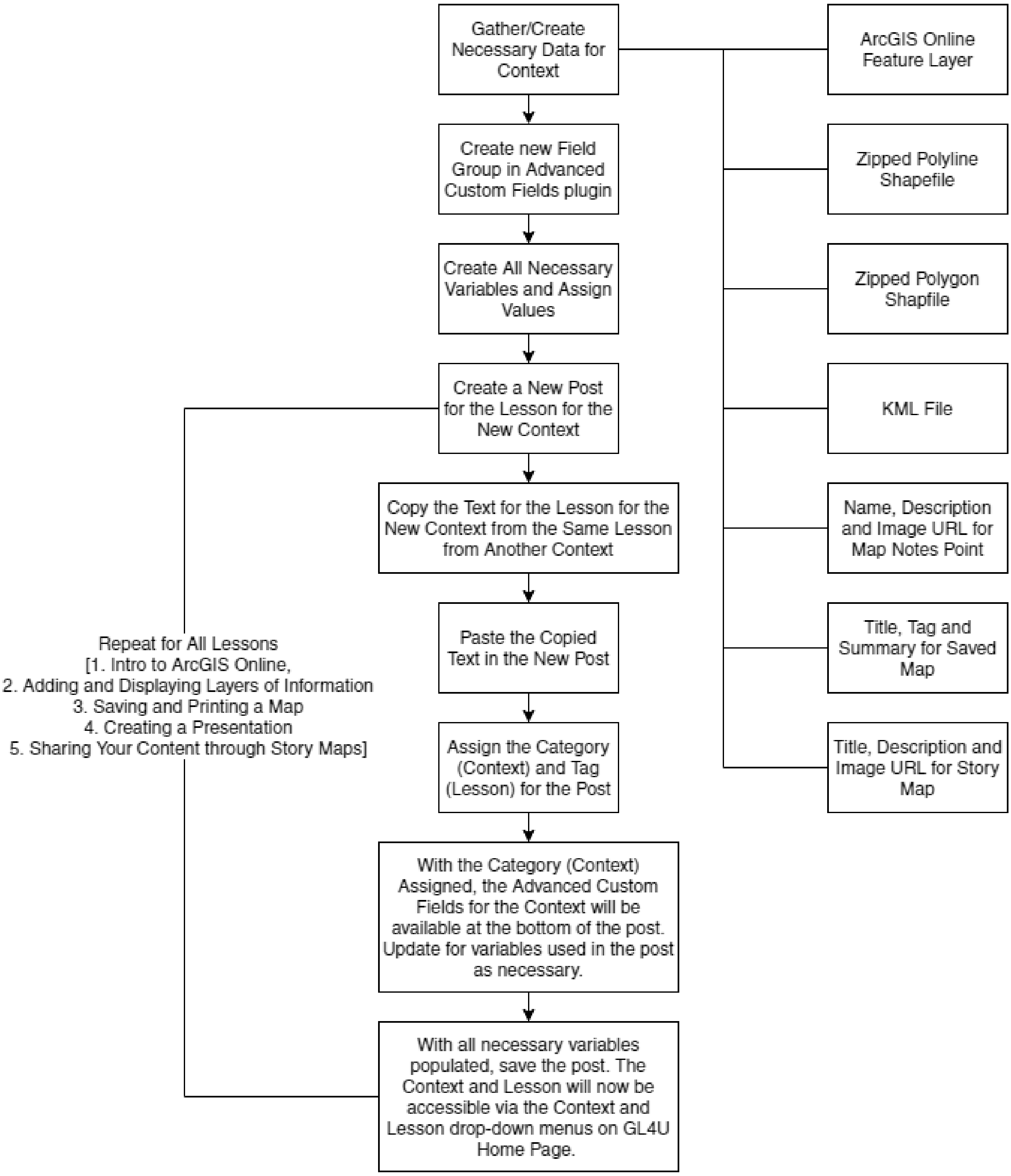


Figure 7.8 Content Creation Process for GL4U

There are, however, certain caveats with regard to context creation that need to be noted. Any lessons that this process is not carried out for will not show up in the lessons drop down for the context. Similarly, should a new lesson be created that would be needed for a context, that lesson would not be available to other contexts unless it was created for them as well. New lessons would also likely require further fields to be added to the Field Group for the context(s) that the lesson would be for, which may prove difficult for long-term sustainability.

7.4 Accessing Contexts and Lessons in GL4U

Based upon those potential learning opportunities detailed in 7.2 Interdisciplinary Learning Opportunities for GL4U, the following contexts were created for GL4U:

- Disaster Planning in Seattle: This context uses data in Seattle to show evacuation routes, seismically hazardous areas, meeting locations and earthquakes that have occurred in the last 24 hours; this information may be used to help people pull together an evacuation plan in the event of an earthquake.
- Water Access in Lima: In this context, users explore data from Lima on water lines and areas, fire stations and historic points to understand their access to services in the event of a fire.
- Medieval Swansea: Data This context is about historic narrative routes, points of interest, and historic maps of Swansea that shares stories of people from medieval times.

A further context titled “Generic” was also created for the purpose of later testing this system with a non-relevant or abstract context to introduce concepts using generic terms for data (e.g. point, line, polygon) rather than meaningful, context relevant ones (e.g. historic building, river, lake). This was based around a context of cases of tuberculosis in Lima, but the contextually relevant information was removed.

With the lessons and initial contexts created, GL4U was officially launched in June 2015 and was showcased at the 2015 Esri User Conference in San Diego, CA; screenshots from the system may be seen in Figure 7.9 - Figure 7.13.

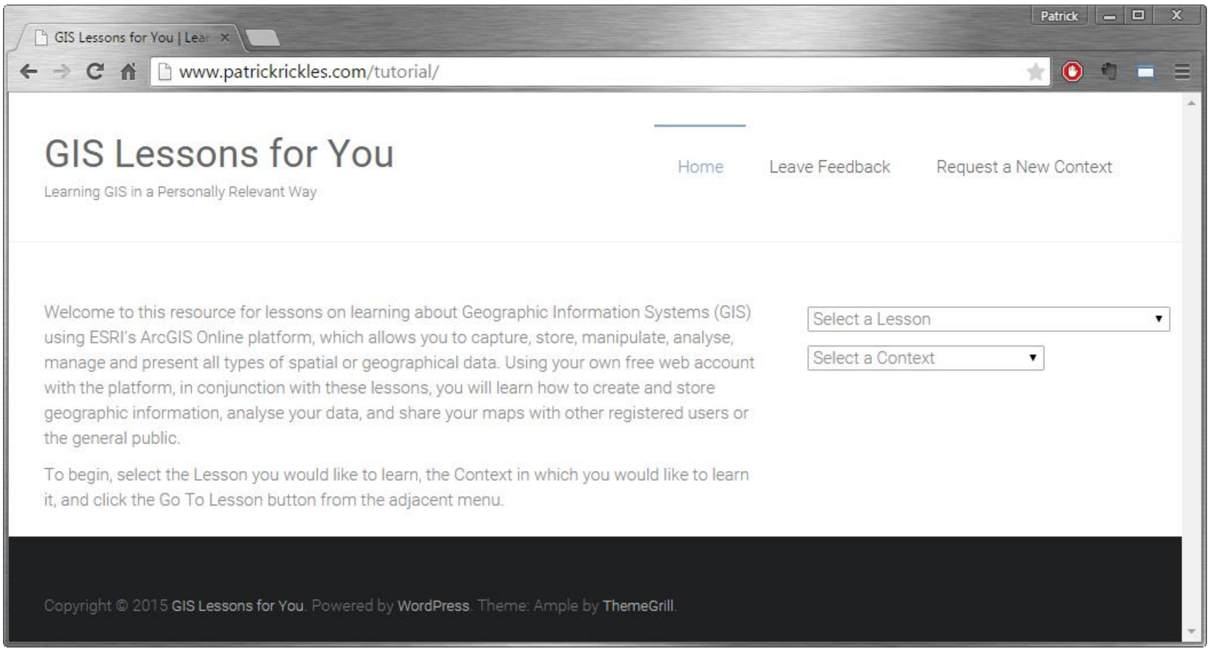


Figure 7.9 Home page for GIS Lessons for You

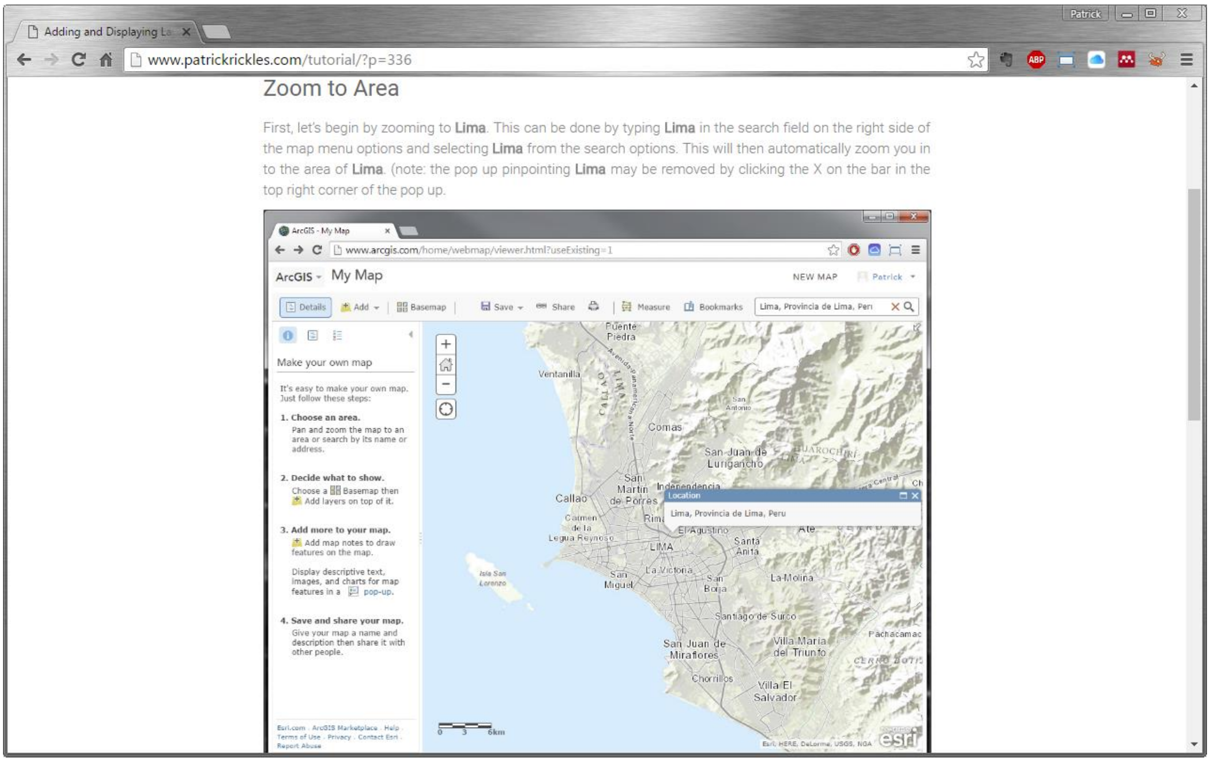


Figure 7.10 Lesson 2 (Adding and Displaying Layers of Information) Step 1 (Zoom to Area) in the context *"Water Access in Lima"*

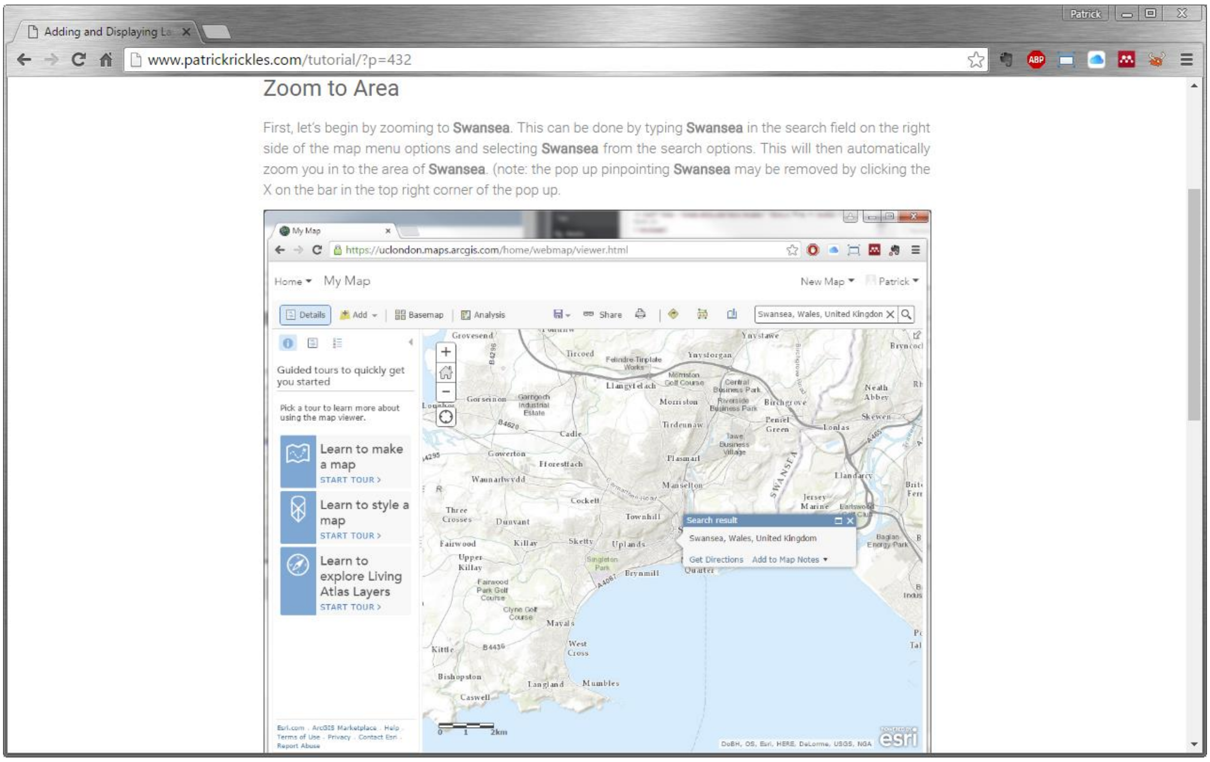


Figure 7.11 Lesson 2 (Adding and Displaying Layers of Information) Step 1 (Zoom to Area) in the context *"Medieval Swansea"*

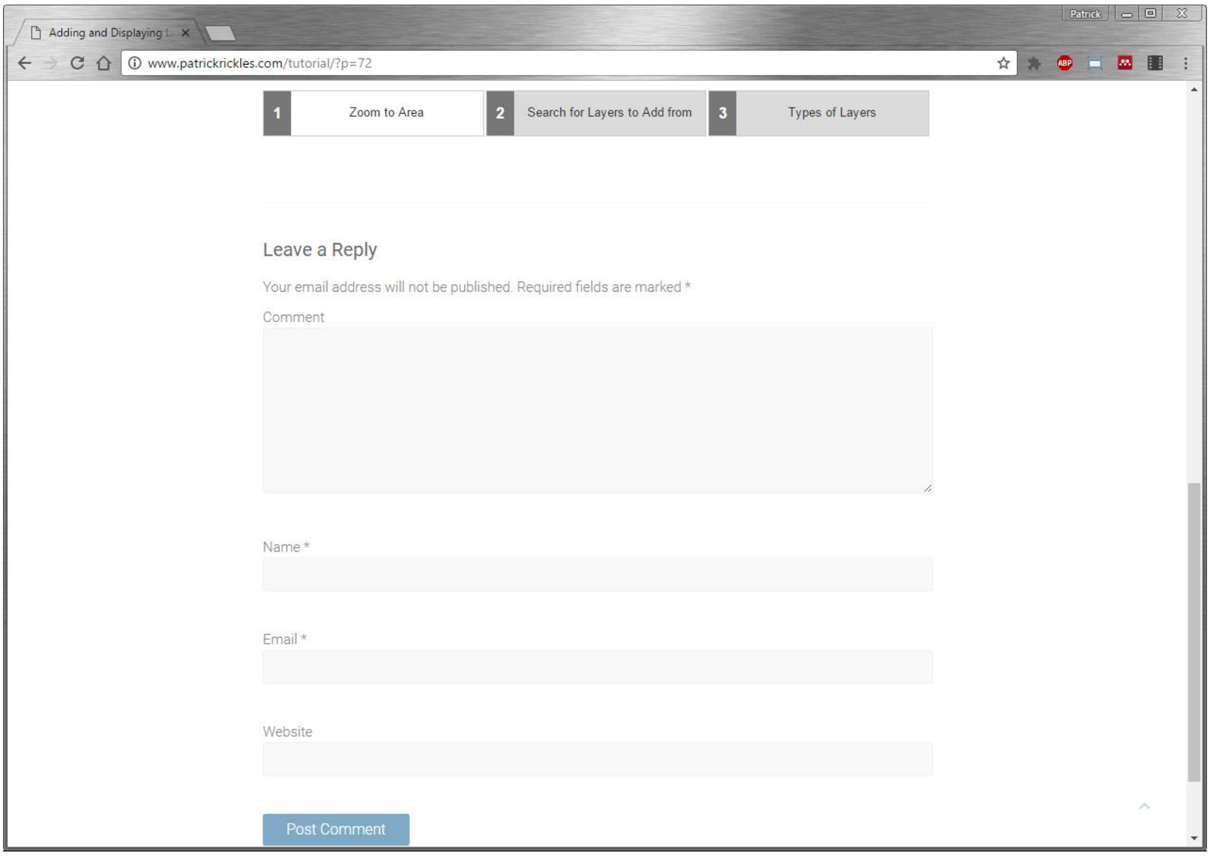


Figure 7.12 Bottom part of the page of Lesson 2 (Adding and Displaying Layers of Information), Step 1 *(Zoom to Area) in the context "Water Access in Lima"*

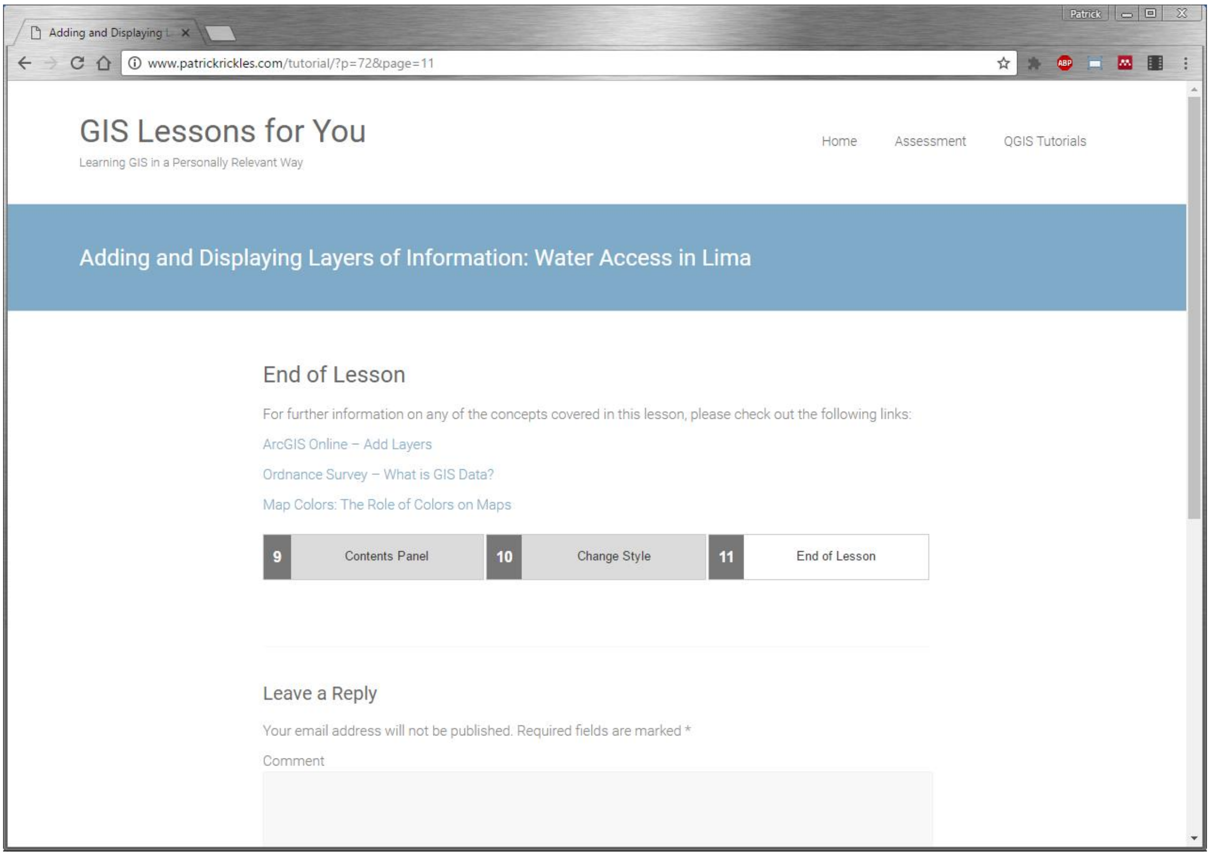


Figure 7.13 Lesson 2 (Adding and Displaying Layers of Information), Step 11 (End of Lesson) in the context *"Water Access in Lima"*

To access the lesson, the learner begins by selecting a lesson and a context from the home page, as can be seen in Figure 7.9; a button then appears that says "Go to Lesson", which the user clicks and it takes them to the lesson and context of their choice. Inspecting Figure 7.10 and Figure 7.11, it can be seen that key variables in bold (e.g. "Lima" in Figure 7.10 and "Swansea" in Figure 7.11) as well as the screenshots are different; these elements are updated in the system on the fly based upon which context the learner selects. The user will then follow the tutorial in another internet browser window or tab using ArcGIS Online with their own account and can progress through the steps by selecting the next step, which follows after the current step's text and images (e.g. in Figure 7.12, by selecting "2 Search for Layers to Add from [ArcGIS Online]"). At any point in time while using the tutorial, should the learner wish to ask a question, they may post a comment to the lesson by entering in their comment, name, email and website URL (if desired) and clicking Post Comment. This would then leave their comment to be moderated by the administrator of GL4U (i.e. the researcher); should their comment be considered a query that may be of use to other learners, it would be added to the lesson. At the end of each lesson, the final step, titled “End of Lesson”, lets the user know that they have come to the end of the lesson and provides them with links to further resources on the concepts covered in the lesson (Figure 7.13). From there, the user may return to the home page, select the next lesson, using the same context, and after clicking “Go to Lesson” will be taken to the next lesson.

With the system described, details on the teaching undertaken and the use of GL4U will be described in the following sections and results will be disseminated to examine if CBL plays any significant role in learning and uptake of GIS in IDR. Later work was carried out to also compare formal and informal learning approaches through an experiment, which will be discussed in Chapter 8.

7.5 Using GL4U in Formal Education with Interdisciplinary Learners

GL4U was used as a teaching resource with the DPU and Digital Humanities, described in 7.2 Interdisciplinary Learning Opportunities for GL4U, as part of one of the modules in the students’ course at UCL in 2015 and 2016. Prior to teaching, labs with computers with network access were booked and ArcGIS Online accounts were set up for students based on the student list supplied by the course directors. These accounts were given basic privileges, which were adequate for completing the lessons in GL4U; this meant that less time was required for account creation and students could immediately begin with system familiarisation and start the lessons in GL4U. At the beginning of the session on ArcGIS Online, students were randomly assigned the context in which they were to take the lessons – either “Water Access in Lima” or “Generic” for the session at the DPU or “Medieval Swansea” or “Generic” for the session with Digital Humanities. Students then began the lessons in GL4U using the context they were assigned at the beginning of the session. As students progressed through the lessons, they were encouraged to ask questions when they did not understand any concepts or language used. The final output of all the lessons in GL4U was an ArcGIS Online Story Map, providing a narrative based around the taught context (Figure 7.14, Figure 7.15 and Figure 7.16).

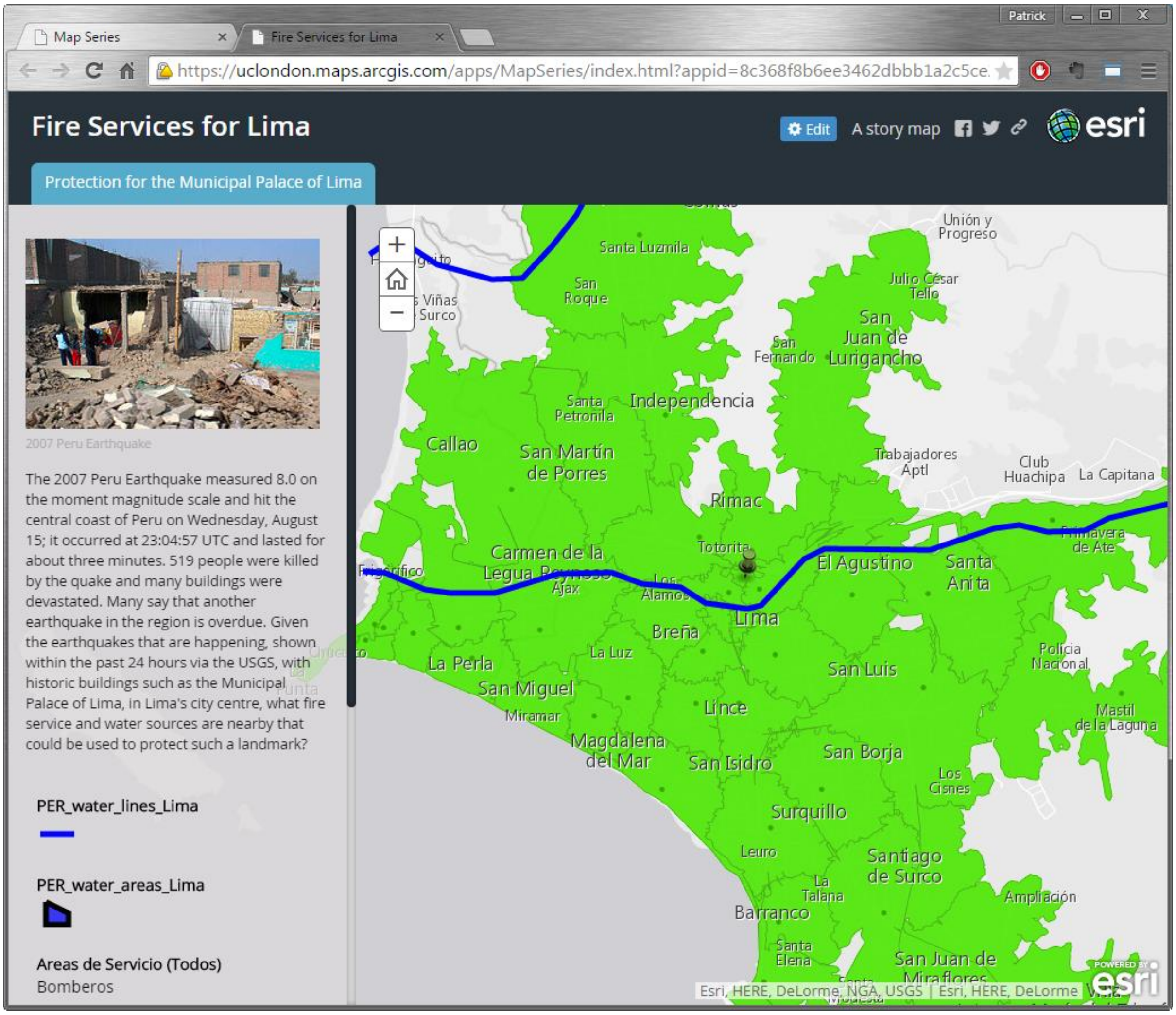


Figure 7.14 *Story Map produced at the end of "5. Sharing Your Content through Story Maps" for the context "Water Access in Lima"*

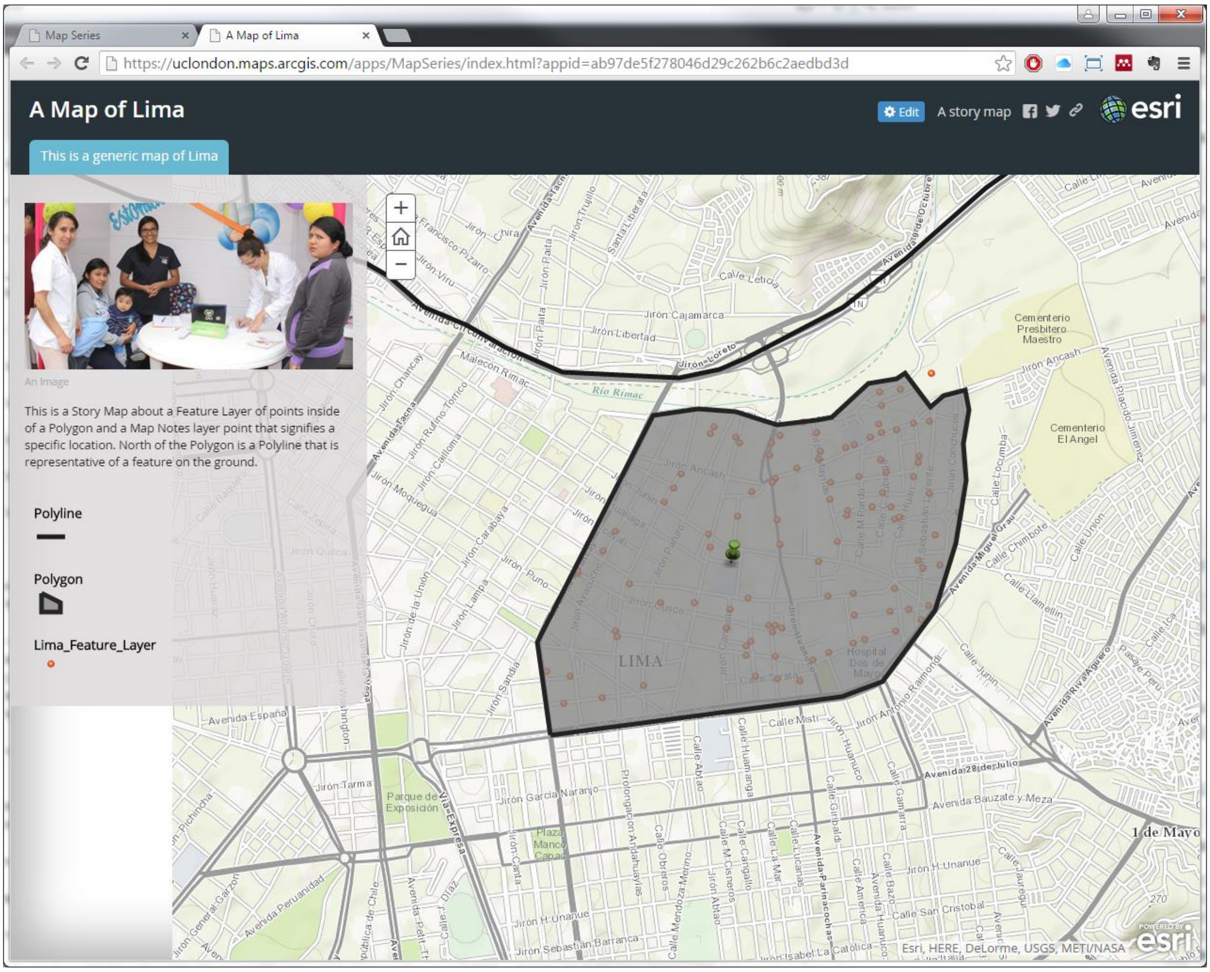


Figure 7.15 *Story Map produced at the end of "5. Sharing Your Content through Story Maps" for the context "Generic"*

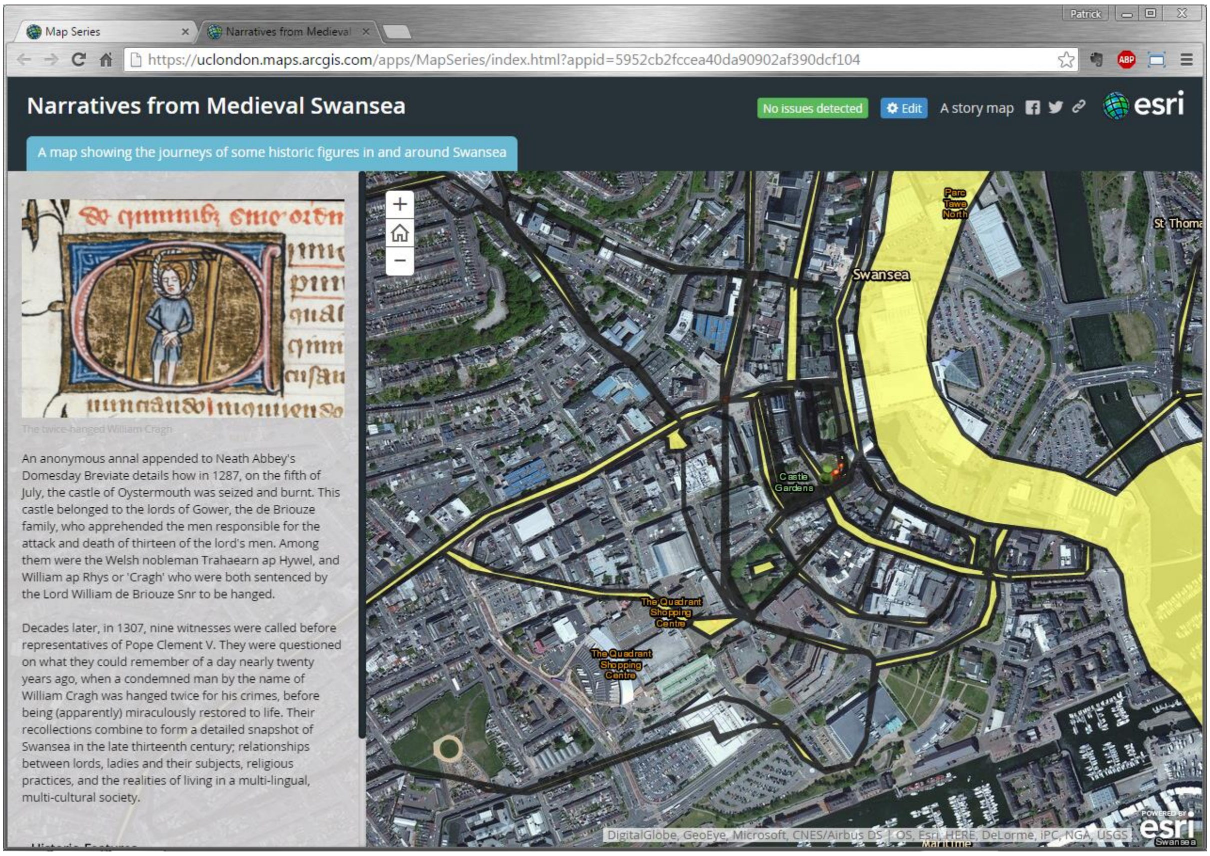


Figure 7.16 *Story Map produced at the end of "5. Sharing Your Content through Story Maps" for the context "Medieval Swansea"*

Each Story Map was evaluated to ensure students had learned and applied the concepts that were covered in steps in the lessons; these were as follows:

- Ability to move around and zoom in/out on the map
- Change the basemap
- Search for and add a layer from ArcGIS Online
- Add a Shapefile from their computer
- Change the style of a layer
- Add a KML from a remote source
- Add a Map Notes layer
- Add a point with information to the Map Notes layer
- Save the map
- Share the map
- Create a Web Map Application from the map
- Add text and an image to a created Story Map
- Save the created Story Map (which was considered finishing the Story Map and the final lesson in GL4U)

After finishing the lessons in GL4U, students were asked to complete a short survey to collect background information (e.g. prior experience with GIS, home discipline, email address) as well as to find out about how long it took for them to complete the lessons, which context they used and their experiences associated with learning GIS. These questions, which are available in A.5.3 Survey Questions – Post Practical 1 Survey along with the students' responses, were asked to see how students' background factors and/or the context for the lessons may have positively or negatively affected their learning experience and if there were any emerging patterns.

A follow up session was later held in which students were asked to create a similar ArcGIS Online Story Map to the one created in the previous session. These were evaluated in the same way the maps were after finishing GL4U. This was to see if students had retained the knowledge of the GIS concepts they had learned and how to use ArcGIS Online. As skills tend to decay with the passage of time if not applied (Rose and Wheaton, 1984; Farr, 1987), it was hoped that through using relevant contexts, learners would have developed multiple memory retrieval cues to help recall information (Halpern & Hakel, 2003). This would then enable them to complete creation of the Story Map with perceived ease, which may be attributable to their learning experience. Students from the DPU were asked to create a Story Map on Building Collapses in Lima (Figure 7.17) and Digital Humanities students were asked to create one on Bombs Dropped on London during World War 2 (Figure 7.18). For this, students were not allowed to use GL4U, though they could seek out information from other sources online to help them in the construction of the new Story Map, and were asked to record how long it took them to finish it. Students were then asked to complete a short survey to report their Story Map completion time and how they felt the context of the lessons they used in GL4U may have positively or negatively affected their learning experience, now that they have had time to reflect on their original learning experience and apply those learnings again. The questions for this survey, as well as individual responses, are available in A.5.4 Survey Questions – Post Follow-Up Practical Survey. This was to see if students could recall the steps necessary to produce a Story Map, if there were any common steps they struggled with and if there were any patterns around how long it took for them to create it based on the context they used for the lessons in GL4U and its relevance to their discipline.

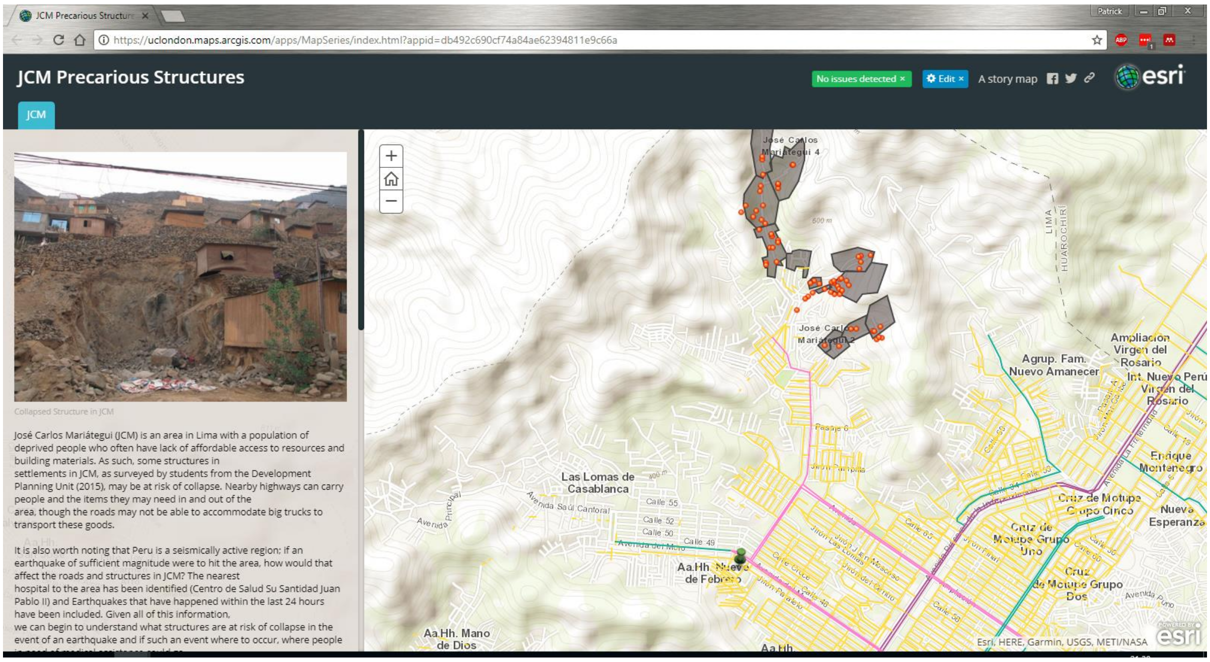


Figure 7.17 Story Map produced in the DPU Follow-Up Session on Precarious Structure in Lima

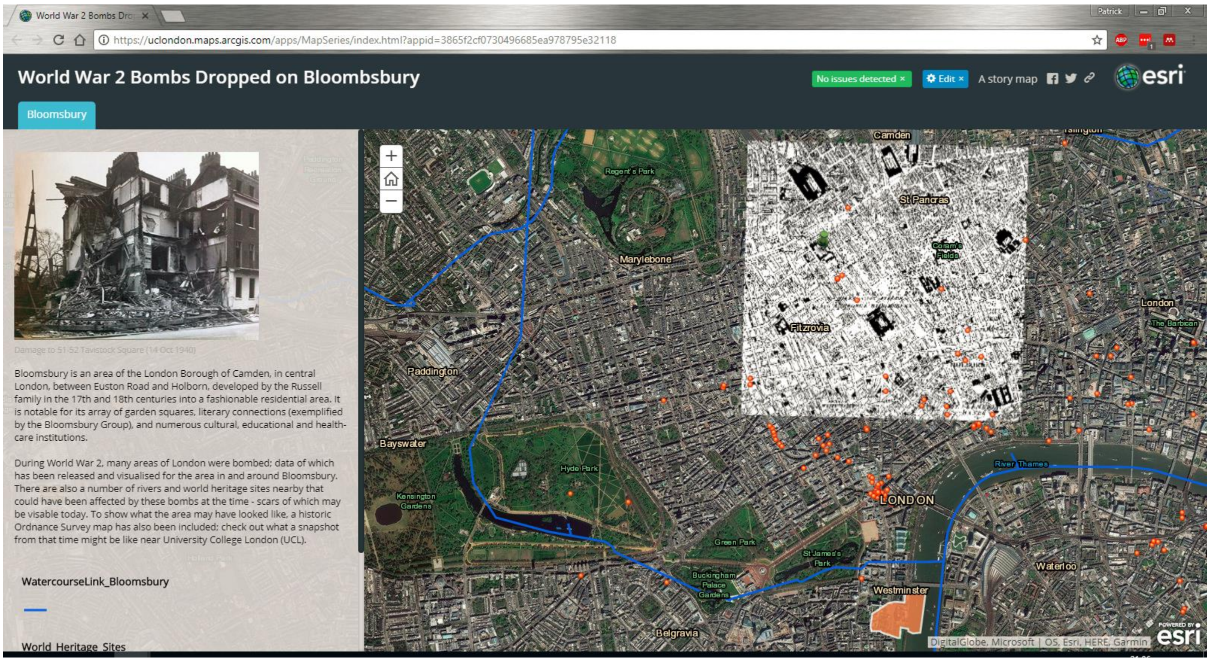


Figure 7.18 Story Map produced in the Digital Humanities Follow-Up Session on Bombs Dropped on London during World War 2

The first session on ArcGIS Online was delivered in November 2015 to the first DPU cohort of 40 students. Due to issues with space in the computer lab and that the GIS practicals were optional, only 25 students were able to and interested in attending the face-to-face practical; however, as materials were available online, others could do the lessons in their own time using their computers. In total 11 students filled out the survey given after the lesson; 10 had completed the lessons in the face-to-face practical and 1 student had completed them online. The second DPU cohort, taught in November 2016 was comprised of 40 students, 20 of which attended the first optional GIS practical. All 20 students that participated did the lessons in a face-to-face practical, with 18 students from this cohort completing the survey. From the DPU, 5 students participated in the follow-up practical from the first cohort and 2 students from the second cohort, all of which completed a follow up survey.

The first session with the first cohort from Digital Humanities, in which students were taught ArcGIS Online, was delivered in December 2015 and for a second cohort was delivered in March 2016. From the first cohort and the second cohort, all 15 registered students attended this face-to-face practical as it was made mandatory to their module. 13 of the 15 students from the first cohort completed the initial survey and from the second, 12 of the 15 students. For the follow-up practical, which was optional, 5 students participated from the first cohort and 9 students from the second cohort, all of which completed a follow up survey.

Table 7.5 summarises the numbers and details for teaching experiences with both the DPU and Digital Humanities and the following sections will explore the results of these, based on the survey results and the reflections the students shared.

Table 7.5 DPU and Digital Humanities – Teaching Cohort Details and Summaries

				Practical 1			Follow-up Practical		
Group	Year	Month	Number of Students	Mandatory or Optional	Attendees	Surveys Completed	Mandatory or Optional	Attendees	Surveys Completed
DPU	2015	November	40	Optional	25	11	Optional	5	5
Digital Humanities	2015	December	15	Mandatory	15	13	Optional	5	5
Digital Humanities	2016	March	15	Mandatory	15	12	Optional	9	9
DPU	2016	November	40	Optional	20	18	Optional	2	2

7.6 Results

7.6.1 DPU

From the surveys, which were completed after the first practical using GL4U and the follow-up session, students responses from the DPU from both cohorts may be seen in Table 7.6.

Table 7.6 Summarised Student Responses to GL4U Surveys (DPU)

		DPU – Nov 2015	DPU – Nov 2016	Total
Level of Experience with GIS	No Experience	7	12	19
	Basic Experience	1	5	6
	Intermediate Experience	3	0	3
	Advanced Experience	0	1	1
Context	Relevant	2	10	12
	Non-Relevant	9	8	17
GL4U Completion Time	Less than 1 hour	0	0	0
	More than 1 hour	3	9	12
	More than 2 hours	6	8	14
	More than 3 hours	2	1	3
Learning Approaches Mentioned	Take a Course	2	2	4
	Online Tutorial	5	7	12
	Watch a Video	4	9	13
	Internet Search	3	7	10
	Ask Someone More Experienced	3	1	4
	Read a Book	0	1	1
	Learn by Doing	0	0	0
	Not Sure	1	1	2
GIS&T BoK Knowledge Areas	Cartography and Visualization	9	7	16
	Geospatial Data	2	8	10
	Analytical Methods	0	6	6
	Conceptual Foundations	0	3	3

	Organizational and Institutional Aspects	0	1	1
Follow-up Activity Completion Time	30 Minutes	1	1	2
	40 Minutes	4	0	4
	1 Hour	0	1	1

Combining the results from both cohorts, with respect to the survey question on disciplinary background, students identified themselves as being from Environmental Studies [7 students], Biology [1 student], Planning and Development [6 students], Business and Economics [3 students], Political Science [2 students], Architecture [2 students], Agronomy [2 students], Anthropology [1 student], Psychology [1 student], Geography [2 students], and Engineering [1 student]; 1 student did not answer.

Students were also asked to disclose their level of experience with GIS – 19 students had no experience with GIS (66%), 6 students had basic experience (21%), 3 students had intermediate experience (10%), and 1 student had advanced experience (3%).

With regard to the context of the lessons, 12 students had completed the relevant context (“Water Access in Lima”) (41%) and 17 had completed the non-relevant context (“Generic”) (59%).

For completion time of all lessons in GL4U, 48% of students completed in more than 2 hours [14 students], 41% finished in more than an hour (but less than two hours) [12 students] and 10% took more than 3 hours to get through all the lessons [3 students].

If students needed to learn GIS on their own, they said they would have taken a course (14%) [4 students], completed an online tutorial (41%) [12 students], watched a video (45%) [13 students], performed an internet search (34%) [10 students], asked a more experienced person (14%) [4 students], read a book (3%) [1 student] and 2 students (7%) said they were not sure how they would do it.

With concepts framed by the GIS&T BoK KAs, 16 students were interested in topics from Cartography and Visualization (55%), 10 students were interested in those from Geospatial Data (34%), 6 students were interested in Analytical Methods topics (21%), 3 students were interested in topics from Conceptual Foundations (10%) and 1 student was interested in topics associated with Organizational and Institutional Aspects (3%).

Responses to questions on the learning experience and aspects associated with GL4U are as follows:

- Students were asked what their motivations were for learning GIS, of which, only 1 student (3%) stated they took the class due to being required to do so and the others [28 students] (97%) took it due to genuine interest in learning GIS.
- 93% of students [27 students] gave positive feedback on GL4U; however, 2 students (7%) felt the lessons were either difficult or confusing.
- 21 students (72%) felt that the context they learned in positively affected their learning experience, which included a mix of people learning in the relevant context [7 students] (24%) as well as non-relevant context setting [14 students] (48%). 1 student (3%) who did the non-relevant context stated that they felt their learning experience was negatively affected, due to the terms and ideas being too abstract. Similarly, 1 student (3%) who did the relevant context stated that they felt the non-relevant context might have more positively affected their learning experience, as they considered the context relevant information to be “extra information”, which they found slightly confusing. Some students did not comment on how context affected their learning experience; 2 students (7%) were not sure if it positively or negatively affected them, 3 students (10%) did not finish the lessons so they did not comment and 1 student (3%) simply did not respond.

After the initial session, students were invited to participate in a follow up assessment on ArcGIS Online, which occurred four weeks after the initial session. Students were given similar data to those they worked with in that first session; however, all students were given data to create a contextually relevant Story Map – this one on incidents of building collapse in Lima.

Again, 5 students participated in the assessment from the first cohort and 2 students from the second cohort, all of which completed a follow up survey. 2 students finished in 30 minutes or less (29%) [1 student learned using the relevant context (Water Access in Lima) and 1 student used the non-relevant context (Generic) in GL4U], 4 students finished around 40 minutes (57%) [1 student who used the relevant context and 3 the non-relevant context], and 1 student finished in closer to an hour (14%) [the student used the relevant context].

During the assessment sessions, recordings were made of interactions with participants with their consent. Notes were transcribed from the recordings (listed in A.5.5 Follow-up

Sessions – Notes and Recordings), where some students felt that learning with a relevant context was a better approach:

> *"… I think it was better to have [the lessons] more related to our topic."* (Student who took the relevant context)
>
> *"I think it would've been more difficult if it [the context] was irrelevant."* (Student who took the relevant context)
>
> *"With all our other priorities, I think I'd really prefer to learn it [the lessons] in the context already."* (Student who took the relevant context)
>
> *"The context in which I learned, focusing on Water Access in Lima, positively* affected my learning experience as I was able to utilise the information in my *work."* (Student who took the relevant context)

Others felt the non-relevant context was better:

> *"I liked the generic one…"* (Student who took the non-relevant context)
>
> *"I learned generically. During the assessment, I felt I was quickly able to* remember how to complete the task, I believe, because my generic learning just *taught me functionality without distracting with details."* (Student who took the non-relevant context)

Perhaps, though, from discussions with students, it could be said that they seemed to appreciate learning in the context they learned the lessons in, regardless of whether it was the non-relevant or relevant context. More importantly would be their ability to apply what they have learned to other contexts, which one student felt confidently about:

> *"I think if I even started working in the [relevant] context directly, I'd still be able to extract the information I need for another context."* (Student who took the non-relevant context)

7.6.2 Digital Humanities

From the surveys, which were completed after the first practical using GL4U and the follow-up session, students' responses from Digital Humanities from both cohorts may be seen in Table 7.7.

Table 7.7 Summarised Student Responses to GL4U Surveys (Digital Humanities)

		Digital Humanities – Dec 2015	Digital Humanities – Mar 2016	Total
Level of Experience with GIS	No Experience	12	11	23
	Basic Experience	0	0	0
	Intermediate Experience	0	1	1
	Advanced Experience	1	0	1
Context	Relevant	7	6	13
	Non-Relevant	6	6	12
GL4U Completion Time	Less than 1 hour	2	1	3
	More than 1 hour	11	5	16
	More than 2 hours	0	4	4
	More than 3 hours	0	2	2
Learning Approaches Mentioned	Take a Course	1	0	1
	Online Tutorial	9	3	12
	Watch a Video	3	4	7
	Internet Search	5	1	6
	Ask Someone More Experienced	0	0	0
	Read a Book	0	1	1
	Learn by Doing	2	1	3
	Not Sure	2	1	3
GIS&T BoK Knowledge Areas	Cartography and Visualization	6	6	12
	Geospatial Data	4	2	6
	Analytical Methods	0	1	1

	Conceptual Foundations	0	1	1
	Organizational and Institutional Aspects	0	0	0
Follow-up Activity Completion Time	30 Minutes	4	1	5
	40 Minutes	1	4	5
	1 Hour	0	4	4

Reflecting upon their compiled answers from the survey from both cohorts, students identified their disciplinary backgrounds as being from English [4 students], History [3 students], French [1 student], Political Science [1 student], Computer Science [2 students], Language Studies [7 students], Management Studies [1 student], Psychology [1 student], Classical Studies [1 student], Physics [1 student], Literature Studies and Communication Studies [2 students].

With regard to students' existing level of experience with GIS, almost all of the students had no prior experience with GIS (92%) [23 students]; only one student had intermediate experience (4%) and one with advanced experience (4%).

Students who answered the surveys divided almost evenly with regard to those who had completed the relevant context ("Medieval Swansea") (52%) [13 students] and those who had completed the non-relevant one ("Generic") (48%) [12 students].

For completion time of all lessons in GL4U, the majority of students finished in more than one hour (but less than 2 hours) (64%) [16 students], some took more than two hours (but less than 3 hours) (16%) [4 students], 3 students finished in less than an hour (12%) and 2 students took more than three hours (8%).

If they needed to learn GIS on their own, students said they would have taken a course (4%) [1 student], completed an online tutorial (48%) [12 students], watched a video (28%) [7 students], performed an internet search (24%) [6 students], read a book (4%) [1 student], learned by doing (12%) [3 students] and 3 students (12%) said they were not sure how they would do it. No one said they would ask a more experienced person for help, though this emerged as a common option in earlier work (4.2 Online Survey and 5.1 One-on-One Interviews).

Framed by the GIS&T BoK KAs, 12 students expressed interest in topics from Cartography and Visualization (48%), 6 students were interested in topics from Geospatial Data (24%), 1 student in Analytical Methods topics (4%) and 1 student in topics from Conceptual Foundations (4%).

Responses to questions on the learning experience and aspects associated with GL4U are as follows:

- With regard to students' motivations for learning GIS, only 8 students (32%) said it was because they were motivated to learn GIS; the majority (68%) [17 students] participated in the session because it was required for their course.
- The majority of feedback received on GL4U was positive (88%) [22 students]; 3 students (12%) found the GIS or instructions difficult to understand.
- More than half the students (64%) [16 students] felt that the context in which they learned the lesson positively affected their learning experience, which included a mix of students who had learned with a relevant context (36%) [9 students] and non-relevant context (28%) [7 students]. 4 students (2 who did the relevant context and 2 who did the non-relevant context) felt their learning experience was negatively affected by the context they used, largely based on not knowing what they were doing.

After the initial session, students were invited to participate in a follow up assessment on ArcGIS Online, which occurred one week after the initial session. In the follow up session, students were given similar data to that which they worked with in the initial session; however, all students received data considered to be contextually relevant to them to create a new Story Map – this one on historically bombed sites in London during World War 2.

Again, 5 students participated in the assessment from the first cohort and 9 students from the second cohort, all of which completed a follow up survey. 5 students finished in 30 minutes or less (36%) [3 students learned using the relevant context (Medieval Swansea) and 2 students used the non-relevant context (Generic) in GL4U], 5 students finished around 40 minutes (36%) [2 students who used the relevant context and 3 the non-relevant context], and 4 students finished in closer to an hour (29%) [2 students used the relevant context and 2 the non-relevant context].

During the assessment session, a recording was made of the interactions with participants with their consent. Notes were transcribed from the recordings (listed in

A.5.5 Follow-up Sessions – Notes and Recordings), where findings of relevance are as follows:

- There were a number of simple errors (e.g. going to the wrong website, etc.), but students helped each other and joked with one another to keep a light mood.
- Questions were asked around some of the terminology of ArcGIS Online (e.g. “Generalize or Keep Features”, “Summary” (with regard to describing the layer), etc.).
- Students felt familiar with the interface and steps, actively recalling the lesson they had previously completed, and made lots of positive comments (e.g. “I like this”, “this is easy”, “I’m proud of my map”, etc.)
- Reflecting on the non-relevant context, one student, who had taken that context, felt the assessment was easier because they knew what the data were that they were working with – “It wasn’t meaningless data.”
- For those who took the relevant context, they felt the context helped them concentrate, but it was not entirely contextually relevant either, as they came from a variety of disciplines and were doing different things. Some felt that another context, such as the U.S. elections would have helped them learn GIS better because it is something current and of interest to some participants.
- As was sometimes seen, students would blame themselves for their lack of aptitude with the technology, rather than the technology for being confusing.

7.7 Investigation into Student Applications with GIS

After GIS training was given to students in the DPU and Digital Humanities, the researcher followed up with the course tutors and students regularly to offer further assistance. From Digital Humanities, none of the students came back to either the author or their course tutor with further questions or interest in GIS, so it cannot be said whether there was any uptake of GIS with either cohort from this group. Furthermore, none of the students had logged back into the ArcGIS Online accounts that had been created for them since the training. Therefore, any implications of context positively or negatively contributing to uptake are inconclusive; also, their perceptions of the learning experience overall were positive, regardless of the context they learned GIS in, which does not yield any definitive results in favour of or against the use of a relevant LAC.

In comparison to Digital Humanities, though, some students from the DPU continued to use GIS and did ask the researcher for occasional help, as it was part of the required group work in order to complete their programme. Again, as time had progressed, if they did not use what they had learned to do with GIS, those skills would decay (Rose &

Wheaton, 1984; Farr, 1987). However, asking the researcher could be considered relearning forgotten concepts, which can be completed relatively quickly if intervals between not using GIS were short (Rose & Wheaton, 1984; Farr, 1987). As such, the students' continued use of GIS (or not) and relearning concepts as needed were of interest to this research. Students from the DPU Nov 2016 cohort were followed up with more closely, in comparison to the Nov 2015 cohort as the tenets of this work were still being developed, to better understand how their groups used and applied GIS. Students were divided into six groups, each analysing an area of Lima – Barrios Altos, Chuquitanta, Costa Verde, El Agustino, José Carlos Mariátegui and Pachacamac. These groups focused on collecting, analysing and discussing information from a variety of sources in order to holistically understand the issues people face with regard to water access in their group's area. This could be from Agribusiness taxing water resources to irrigate crops, industrial manufacturers polluting water sources or unequal access to water based on socio-economic factors. Using GIS was one of a variety of analytical techniques available to students; others included qualitative interviews with residents, analyses around the impact of government policies and investigations into how stakeholders' agendas may help or hinder improvements. After conducting their fieldwork, representatives from the groups were contacted to inquire about their group's use of GIS. Questions asked were around how their group used GIS, delegated tasks, which platforms were used and if the training adequately prepared them for work that was undertaken in the field. GIS use was optional, though; therefore, should any of the groups not have made use of GIS, it was inquired as to why. The full list of questions asked to group representatives is listed in A.5.6 DPU Applications with GIS – Survey Questions and Responses. Table 7.8 provides a summary of the various groups from this cohort and the sections that follow detail the responses received from each of the groups.

Table 7.8 Summary of DPU Nov 2016 cohort groups – follow-up on GIS use

Group	Number of Students	Number of GIS Users	GIS Platform(s) Used	Summary of GIS Use
Barrios Altos	6	0	None	Did not use GIS as focus was on institutional collaboration.
Chuquitanta	7	1	ArcGIS Desktop	GIS used to create point data from surveys and interviews; training helped with group cohesion and creating a common language.
Costa Verde	7	2	QGIS, ArcGIS Online, EpiCollect	GIS used to create presentations and collect survey data; time constraints were an issue for all group members to attend GIS training.
El Agustino	7	2	ArcGIS Desktop, AutoCAD	GIS used to georeferenced maps; group had one GIS user with advanced experience, so training was not necessary.
José Carlos Mariátegui	7	2	QGIS, EpiCollect	GIS tasks were on basic data and map creation; delegated for division of labour.
Pachacamac	6	1	EpiCollect	GIS used to show land use change in comparison to agricultural land; internet connectivity limited online GIS use and assistance given from other groups.

7.7.1 DPU Group: Barrios Altos

The Barrios Altos group did not use GIS, as they focused on analysing how different institutions could work together in a way that did not require GIS. The group did report, though that had their work involved collecting space-related survey data, they would have used GIS to achieve their objectives.

7.7.2 DPU Group: Chuquitanta

The Chuquitanta group designated one member of the group to handle the GIS work to split responsibilities due to time limitations. GIS was used to create point data from surveys and interviews conducted with local community members and other actors. The group felt QGIS was simpler, in comparison to ArcGIS for Desktop, but the designated person to do the GIS work used ArcGIS, as this was the platform they were more familiar with from previous experience. There was positive feedback on GL4U as the representative from the group shared the following:

> *"… [The GL4U lessons] helped me feel confident, as they were relatively easy to* follow, with a structured exercise that taught me and made me put into practice *the skills simultaneously… This method is definitely more effective than just reading or 'being shown' by someone."*

For their fieldwork, it was felt that most of what was needed was covered in GL4U and the other GIS sessions; no other concepts that were not covered were encountered. Materials tailored to the context, though, were appreciated in highlighting practicality and importance of the work to be undertaken in the field. By going through training together, this group felt that they had the same level of understanding of GIS and were able to have dialogue and integrate their varied knowledge in a "common language". Of particular interest, it was said that GIS "… helped build group cohesion as this was a 'weapon' we used collectively to tackle work demands, so it created an environment where we 'worked together' on it."

Ultimately, this group felt that they would have taken the GIS training program again, as it was perceived to be a more effective, faster and fun way of learning. If not for this course, this group said they would try using other resources (e.g. books, etc.) but believed it would have taken longer and they probably would have abandoned learning GIS because it is a time-consuming process that requires additional will power.

7.7.3 DPU Group: Costa Verde

For Costa Verde, the group designated two members to learn QGIS and one to learn ArcGIS Online and EpiCollect (a mobile data collection platform); this was in order to spread work out evenly and ensure everyone had a fair share to do, but anyone else who wanted to learn on their own was encouraged to do so. This group found ArcGIS Online more user friendly, as they were able to navigate around it more easily than QGIS and utilised its functionality of creating presentations for the data collected from surveys;

QGIS was only used in the beginning to map the study area. GL4U was considered useful, but this introduction to ArcGIS Online could have better highlighted how it can be used to produce relevant outputs to drive home the purpose of the session. As stated by the representative of the group:

> *"I would say that the guide [GL4U] that I fol*lowed was really easy to understand, but I remember I was a bit confused at one point with what exactly I could use the software for and how it could be useful for me. I think it would be useful to have example templates of what each session would achieve at the beginning and the *purpose of the session."*

Some difficulties encountered when using the GIS largely stemmed from issues with getting data into the GIS and displaying correctly, which occurred due to Spanish characters in the text. It was further felt that GIS training as a group could have helped members learn together and fully understand how the applications work; however, time constraints were a limitation and so not all members of the group were able to attend all of the training sessions. There was a desire, though, to attend the sessions, as all group members believed GIS to be a useful tool and having people around who are using it can be helpful, should those learning it have any questions. Learning together was perceived to save time, in comparison to learning by oneself, as group-training opportunities were considered a more efficient method of learning, in comparison to searching the web for a suitable resource. Flexible drop in sessions were also suggested and would have been considered useful.

7.7.4 DPU Group: El Agustino

GIS, particularly ArcGIS Desktop, was used by the El Agustino group, with the initial focus on using it to georeference local maps. These maps were originally in AutoCAD and lacked the geographic coordinates necessary to create printed maps to use in workshops with participants. Two group members did the GIS work, one of which had advanced experience with GIS; as such, GL4U was not necessary, though it was considered interesting as they had not had much experience with online GIS platforms. Story Maps were considered useful, but would have been more so if more analytical tools were also taught as part of the ArcGIS Online lesson. GIS was used in a limited capacity, so it was not considered to contribute positively or negatively to group cohesion. Group members who did the GIS work had said they would not take the GIS training again, upon reflection, but only because they had sufficient previous experience with GIS to do the work that was needed.

7.7.5 DPU Group: José Carlos Mariátegui (JCM)

The JCM group designated two out of the seven members to do the GIS work, as the other members were involved in the remaining tasks (e.g. language translation, video footage editing, logistics planning, etc.). With regard to GIS work, the group members made use of EpiCollect and QGIS, rather than ArcGIS Online; as the internet connection in Lima severely limited data transmission, offline GIS functionality was necessary. The GL4U tutorial was received positively, though group members did not attend the other sessions on QGIS. This was due to lack of time and it was considered difficult to do the tasks in the tutorials without supervision, as the students felt they might get stuck and would not be able to complete the tutorial. GIS was used by the group for basic data and map creation, so group members could not identify specific concepts that were not covered in the session attended that they used in the field. When problems were encountered while doing a task in the GIS, group members would refer to YouTube tutorials because they felt it was easier to follow along with a video. Though they had not attended the further GIS training sessions, group members still expressed interest in doing them face-to-face, rather than online.

7.7.6 DPU Group: Pachacamac

Use of GIS in the Pachacamac group centred around the work completed by a designated group member on using data gathered by EpiCollect to show zones of changing land use in comparison to agricultural land. The person designated to do the GIS work was selected by what they attributed to their “technical know-how” and because they understood the GIS training sessions. Similar to other experiences, ArcGIS Online was difficult to use due to poor internet connection; however, there were also technical difficulties with using QGIS. These were circumnavigated by assistance from one of the group members from the El Agustino group, who was experienced with GIS. GL4U was received positively as it was considered a good introduction to GIS and explained directions in a clear manner. Though creating and printing maps was covered in the sessions, this group felt that further information on the nuances of printing maps (e.g. clear and understandable symbology, logistics of printing, etc.) would have been useful to better prepare for issues experienced in the field. The output maps contributed to communal dialogue; however, as one person was delegated the GIS work, concepts were not understood by other group members. When others attempted to use the GIS, they were said to have struggled with completing the work. Group members did express interest in GIS training in the future that covered a mix of basic and advanced topics in the form of online tutorials that also incorporated YouTube videos.

Reflecting on the training sessions, the GIS group representative suggested that GIS should be a compulsory part of the module and that later sessions should be limited to a smaller number of students. These students may be the designated person or people from the group doing the GIS work and the smaller number of students would facilitate deeper investigation into more advanced topics. In particular, it was noted:

> *"The group sessions appeared to be a lot of people asking questions that were answered in the instructions, not about how to create better content… I think it [GIS] is a really powerful tool when used effectively, but personally, I don't think we were really given enough time to get to grips with some of the more powerful elements..."*

7.7.7 DPU Groups – Summary

Overall, it was seen that, even though 20 of the 40 from this cohort attended the initial GIS tutorial on ArcGIS Online and overall perception of learning GIS, regardless of context, was positive, only 1 or 2 students from each group did any GIS work. This was said by some to be for division of labour to focus and deliver on the various areas of analysis that each group needed to complete; however, it begs the question of why these specific students were either assigned or volunteered to do the GIS work for the group.

Though further supplemental training was offered to this cohort on QGIS and EpiCollect, two groups (Chuquitanta and El Agustino) used ArcGIS Desktop and one (El Agustino) used AutoCAD, which were not platforms that were taught to this cohort. Therefore, it may be assumed that students who did the GIS work in these groups were familiar with these platforms and led on the GIS analyses. Those who were more familiar lent their expertise to others, regardless of the group, as it was stated that someone from the El Agustino group helped the Pachacamac group with GIS work.

Issues with internet connectivity were noted, which may have hindered wider use of ArcGIS Online and necessitated the use of a desktop GIS platform (e.g. QGIS, ArcGIS). Another issue that affected GIS application in this work was around difficulties with the GIS recognising Spanish characters in text. Given the complexity and breadth of the work the students had to complete, time constraints were a concern, which affected the ability for some to attend training. There was, however, interest in learning more on advanced analytical topics with GIS. This may be difficult to do, though, as it is necessary to cover foundational topics for interdisciplinary researchers learning GIS.

7.8 Comparisons and Contrasts Between Digital Humanities and the Development Planning Unit

Looking across both the DPU and Digital Humanities groups, there are some similarities as well differences that are worth noting. Of all students that participated, most [42 of the

54 total students] (78%) had no prior experience with GIS, some had basic experience [6 students] (11%), a few had intermediate experience [4 students] (7%) and 2 students had advanced experience (4%) (Figure 7.19).

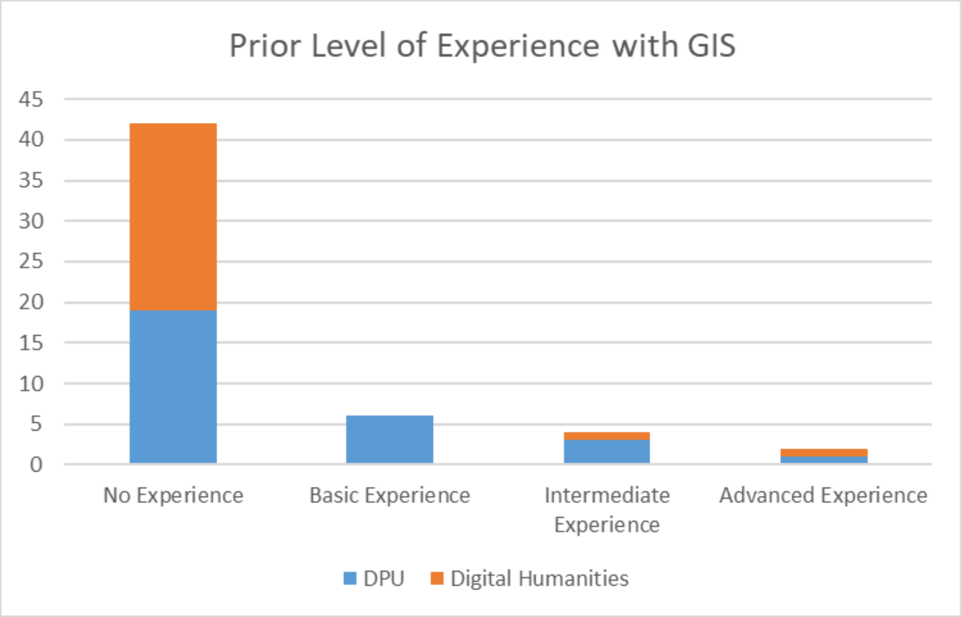


Figure 7.19 DPU and Digital Humanities cohorts – Prior Level of Experience with GIS

Overall feedback on GL4U as a learning resource was positive from most students [49 students] (91%). Reviewing their comparative completion times (Figure 7.20), it can be seen that 3 students (6%) completed the lessons in less than 1 hour, 28 students completed them in more than 1 hour (58%), 18 completed them in more than 2 hours (33%) and 5 students completed them in more than 3 hours.

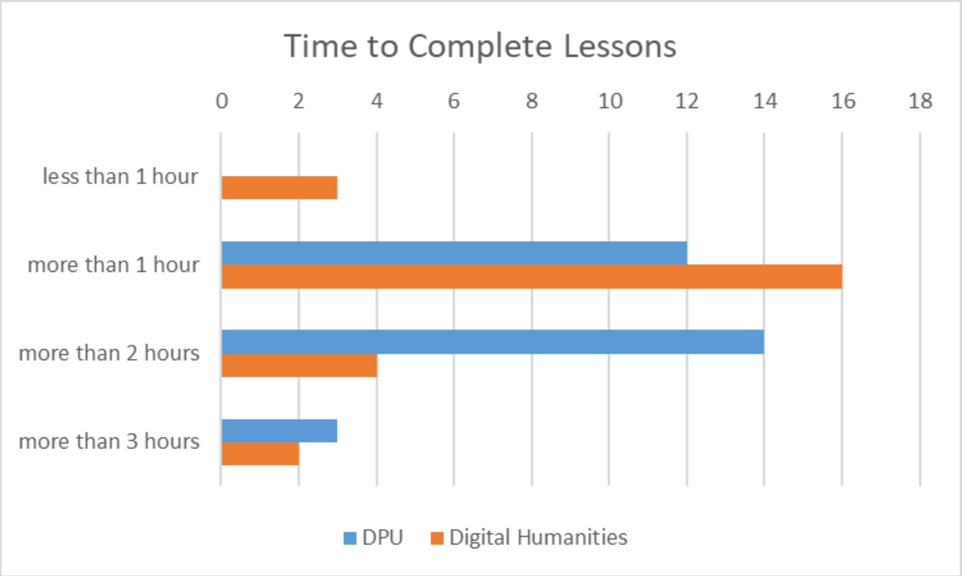


Figure 7.20 DPU and Digital Humanities cohorts – Time to Complete Lessons in GL4U

For the follow-up assessment, most of the students that participated completed creation of a Story Map without reference to materials within 30 minutes [7 of the 21 students who participated in the follow up] (33%) or 40 minutes [9 students] (43%), and the remaining students [5] (24%) finished within 1 hour (Figure 7.21).

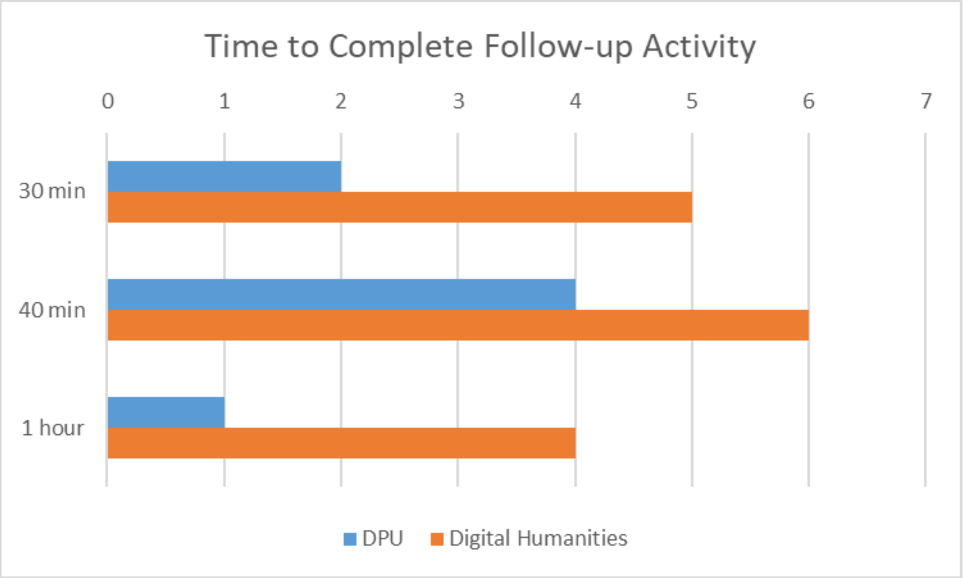


Figure 7.21 DPU and Digital Humanities cohorts – Time to Complete Follow-up Activity

Using GL4U, it seems that most Digital Humanities students were able to get through all the lessons quicker than the DPU students; however, most DPU students were more motivated to learn GIS (93%) in comparison to the Digital Humanities students. Most Digital Humanities students (68%) only attended the GIS training session as it was a requirement for their course. Taking into consideration the responses from all students, when asked about the Knowledge Areas from the GIS&T BoK, Cartography and Visualisation (48%) [26 students], Geospatial Data (30%) [16 students] and Analytical Methods (13%) [7 students] were identified as relevant to the work that many students wished to do; this aligns with findings so far of the prominence of these Knowledge Areas to interdisciplinary researchers. Similarly, with respect to overall findings from this research, when asked which informal learning methods they would use, students identified online tutorials [24 students] (44%), watching a video [20 students] (37%) and searching the internet [16 students] (30%) as ones they would consider.

7.9 Discussion

This research ties together the previously presented theories, results from investigatory work and has tested one of the main research hypotheses using a custom developed system – GIS Lessons for You (GL4U). GL4U was created to address the IDR challenges and suggested solutions identified in 2.1 The Current State of

Interdisciplinary Research. This resource was used with interdisciplinary researchers to Provide Training as part of a collaborative learning environment in formal education, which could help Build Relationships around the use of GIS. The efficiency of the lessons was investigated through this work as interdisciplinary researchers were taught what they needed to know about GIS, framed by the GIS&T BoK (2.4.5 Geographic Information Science and Technology Body of Knowledge), which was derived from preliminary case studies (Chapter 3), published articles (4.1 Google Scholar Analysis), an online survey (4.2 Online Survey), interviews (5.1 One-on-One Interviews) and learning diaries kept by those learning GIS (5.2 Learning Diaries). The focussed lessons of GL4U were meant to help circumnavigate Time Constraint issues associated with learning and bridge the Knowledge Gap between disciplines. From the educational approaches introduced in 2.2 Educational Approaches, the materials were structured using CBL approaches with the focus on testing the relevance of the LAC. As these were all used to construct the Modified TPACK Framework for Interdisciplinary Researchers (Figure 7.1; Rickles, Ellul & Haklay, 2018), the work of this chapter, therefore, provides foundational evidence for this framework's practical application.

To recapitulate, this work was carried out to begin to answer the following research question:

- Can a contextually relevant mixed formal (institutionally led)/non-formal (loosely organised) learning resource improve uptake and application of GIS in IDR?

Based on using GL4U with the DPU and Digital Humanities, it is not particularly clear whether CBL has played a central role in the students' use and uptake of GIS. However, key findings to emerge from this work are as follows:

- GL4U shows successful proof of concept using existing technologies for the creation of a CBL system, which, overall, received positive feedback from students
- Motivation to learn GIS may be an important factor, regardless of LAC
- Identifying and creating LACs relevant to learners from a wide range of disciplinary backgrounds can be challenging
- Even though many within groups were trained, only one or two people were still designated to do the work with GIS

This work also continues to corroborate the findings presented so far in this report. From the GIS&T BoK KAs, Geospatial Data, Analytical Methods and Cartography and Visualization were the most important ones for these interdisciplinary researchers. Use of informal learning methods, such as taking an online tutorial, internet searches and asking a more experienced person are also ones these researchers thought were important and should be taken into consideration for learning resources intended for interdisciplinary researchers.

7.9.1 Review of GL4U and System Limitations

Through development and application of the system on to the role of context itself and beyond, when interdisciplinary researchers learn GIS, there are a variety of issues that may have helped or hindered the learning uptake of GIS that warrant further discussion. The system design, as discussed in 7.1 Aims for GIS Lessons for You (GL4U), required compromise. A totally bespoke system could have been developed that may have better supported the desired functionality. This custom system may have been able to more easily assign and switch variables or include possible integration of an ArcGIS Online interface into the lessons themselves, saving users from having to switch back and forth between tabs/windows. A totally bespoke system may have also been made in a way such that it could more easily stream line context and/or lesson creation. This could be performed through building in prompts for getting the necessary information for text and screenshot variables from those who wish to create them. However, the use of WordPress and its plugins (adapted or otherwise), allowed quick creation of a sufficiently stable system and focus to remain on investigation of research questions, rather than system development or maintenance. The system was also built as a prototype and it was not clear if it would be a necessary for others to create lessons and/or contexts, so functionality to aid their creation was omitted. Indeed, as time progressed, given the shift away from online learning and lack of educators coming forward to use the system, neither this functionality nor detailed process documentation were needed as all contexts/lessons were made by the researcher. Therefore, an unanswered question by the research would be if the system could be better designed in a way that would allow educators to easily create contexts/lessons and, furthermore, if this could be sustained without or beyond involvement of the researcher. As the educator was not necessarily the focus of this research, but rather, the learner, this could be considered outside of the scope of this work. However, further research could investigate the use of and extensibility of this tool, which may perhaps lead to a new, improved and sustainable version.

7.9.2 GL4U Contexts – Strengths and Weaknesses for Investigating CBL in Formal Education

Nevertheless, the educator still plays a vital role in guiding the learner and, in respect to this research, setting the context of the learning activity. Referring back to the proposed framework (Figure 7.1) and the outputs from previous chapters, the LAC was hypothesized as a possible element that, if adjusted such that it was relevant to the learner, the learning experience and uptake of GIS could be improved. With the work now completed, the LAC for learning GIS can begin to be questioned; a student from the DPU noted the following with regard to LAC:

> *"As someone who's brand new to GIS, I think either way [relevant or non-*relevant *context] would've helped, because it s*till shows the significance and the power of *GIS. If you'd given me [U.S.] election stuff, I'm really interested in American politics, so sure, definitely. I feel like if you would've given me stuff from Cameroon, maybe not necessarily; I would've been like 'Oh! What's this about?' but it depends on the context that you're presented with."*

Bearing this in mind, determining a context of interest to the learner may be difficult without consulting them first and then building materials to match that interest. Even on the same interdisciplinary programmes, students were from a variety of disciplinary backgrounds – 11 uniquely identified disciplines from both cohorts from the DPU [11 disciplines] and 11 from both cohorts from Digital Humanities [20 distinct disciplines, in total]. Creating LACs for the lessons that would have been suited to the variety of disciplinary backgrounds from both of these courses would have required initial engagement for material construction and resources to achieve this were not available. The researcher, instead, focused on creating a plurality of contexts to be as relevant to as many of the participating students as possible.

Though GL4U allows simplified creation of context relevant lessons, the system was not contributed to by anyone other than the researcher; if the system had received contributed contexts by a number of educators, the contexts available would have grown and possibly increased the chance of there being a context that a learner would find relevant. It may be suggested that a variety of contexts be created and teaching with GL4U repeated to see which contexts students would chose; this could help better explore the role of the LAC and the suitability of the Modified TPACK for interdisciplinary researchers learning GIS (Figure 7.1), as current results are somewhat inconclusive.

The creation of more contexts outside of the ones created for the projected case studies did not materialise, whether by the researcher or otherwise, as there were no further requests for them. Perhaps a reason for the lack of educators or learners coming forward to request contexts may have been due to the channels used to advertise GL4U. Similar to the Online Survey (4.2 Online Survey), advertising was largely limited to Geography related conferences and through Geography related contacts, as these are within the professional network of the researcher, supervisors and colleagues who shared information on GL4U. These Geographers may have either already been familiar with GIS or had their own tools and methods that they used for geographic analyses that did not require GIS, so they may not have been interested in GL4U. Advertising on other disciplines' professional networks can also prove difficult, as researchers in other disciplines would need to deem GIS relevant in order to consider or pass on information about GL4U; given possible time constraints of researchers, interdisciplinary education with tools thought to be irrelevant may not have been of interest. Again, this is a recognised barrier in interdisciplinary research, as identifying participants outside of one's network to establish communications and contacts is problematic (Augsburg & Henry, 2009).

7.9.3 Interdisciplinary Students and Researchers

The focus of this report has been on interdisciplinary researchers; however, the work of this chapter was carried out with students of interdisciplinary courses. This was partially due to difficulties associated with finding IDR projects using GIS and having long-term engagement with them. The interdisciplinary teaching opportunities, though, were desired by the course tutors, who sought the assistance and expertise of the researcher. The practicals and lessons were then structured, as possible, to deliver materials and teaching in a way that would test the modified TPACK framework for learning GIS in IDR (Figure 6.10) and gather information on the students' GIS learning experiences. As such, the findings from these could be considered translatable to what an interdisciplinary researcher would go through topically to learn GIS and more specifically if they were to do so through a formal educational approach. Indeed, many of the same common informal learning approaches and GIS&T BoK KAs considered relevant as identified by the students in the work of this chapter were equally acknowledged in earlier work (4.1 Google Scholar Analysis, 4.2 Online Survey, 5.1 One-on-One Interviews). This shows the cross-applicability of findings and the similarity of the students and interdisciplinary researchers. The student group work in 7.7 Investigation into Student Applications with GIS may also be considered as individual small-scale IDR projects in their own right. As such, findings from the application of GIS, division of labour and issues faced that were presented may be relevant to larger IDR projects in practice, which should be verified by further research.

7.9.3 GL4U and Motivations and Methods for Learning GIS

Lack of interest or perceived applicability to one's research may have been one of the factors that hindered uptake of GL4U online and led to the inability to further research the dimension of online education; though GL4U was initially intended to be accessed for distance as well as face-to-face learning, it was only used in face-to-face teaching. Considering its initial purpose and as GL4U was constructed as a public resource, the lessons focussed only on functionality within ArcGIS Online that was accessible via a public account. Public accounts have access to a limited number of geoanalytical tools, so the lessons in GL4U did not heavily investigate topics associated with the GIS&T BoK Analytical Methods KA as much as those from Geospatial Data and Cartography and Visualization. Furthermore, the role of forums (in the way of comments that could be posted and associated with the lessons) could not be investigated as a collaborative learning mechanism, as the teaching with GL4U was carried out face-to-face, which made posting questions as comments to the lessons unnecessary – they could simply ask them directly to the educator (in this case, the researcher). Though the scope of the research shifted to accommodate these factors, comparisons between online and face-to-face learning as well as the role of forums in collaborative distance learning may still be tangentially relevant to this work.

Even within the projected case studies, which had dimensions of geographic analyses, learners from Challenging RISK did not come forward to learn GIS and there was no further uptake in Digital Humanities beyond the face-to-face lessons. Though the training materials were made available to them, GIS was not a tool these interdisciplinary learners used for their work. It is worth noting that once Challenging RISK shifted from interdisciplinary to multidisciplinary, the necessity and, by proxy, motivation of researchers from the non-Geography related disciplines to learn GIS evaporated. Similarly, in Digital Humanities, 68% of learners [17 of the 25 students] had reported that they took the GIS training because it was a required part of their course. This suggests that motivation plays an important role in interdisciplinary researchers learning GIS; therefore, either before or in conjunction with investigations into the role of the context of learning activities, learners' motivations should initially be understood and taken into consideration. Should it be possible to identify those with strong initial motivations to learn GIS, those interdisciplinary learners could specifically be supported and aided in exploring GIS concepts in a more in depth manner. This would result in a smaller number of learners, in comparison to teaching to a larger audience that may not have a similar level of motivation, and could provide a more bespoke educational experience, which would address the comment made by the GIS representative from the DPU Pachacamac group.

With regard to findings from following up with DPU students on their group work, the GIS work seemed to be delegated within the groups to the person/people who showed motivation and/or aptitude with GIS. Time constraints were given as a reason that not all group members learned to use GIS; however, without questioning all members of the group, it is inconclusive as to whether this is their actual reason for not doing so. Requiring all students to learn GIS may improve uptake, but not necessarily willingly so. Some did feel that all members of the group having a basic understanding of GIS was beneficial and collaborative learning can be a positive experience, though the time taken to learn GIS is a factor to consider. Suggested ways of further supporting the students could be to offer drop-in sessions for those who may not have been able to attend scheduled sessions or sessions that teach advanced topics, which may be of interest to those who want to do more with GIS. Teaching how to use GIS should also include what to do when things go wrong with the system, as this can happen in the field where support may be limited or unavailable.

7.10 Summary

The findings from this chapter show how a resource such as GL4U could be used to teach GIS within a formal educational setting and to investigate the relevance of LAC. The way that the system was designed and the contexts created for it had limitations; nevertheless, GL4U was used to successfully deliver GIS teaching in formal education with students from the DPU and Digital Humanities. DPU students were more motivated to use GIS than those from Digital Humanities, though follow-up with the Nov 2016 cohort showed that only one or two people did the GIS work in the groups. If these researchers had not received training using GL4U, it may be assumed that they may use informal learning approaches (e.g. internet searches, watch a video, etc.), based on how previous interdisciplinary researchers learned GIS. Therefore, it may be questioned how the efficacy of GL4U compares to methods that would be used in a real-world setting. In the next chapter, work that was undertaken to compare formal and informal learning methods will be discussed. From which, the role of context may be further investigated as well as the suitability of the structure of GL4U as a resource for interdisciplinary researchers for learning GIS.

Chapter 8 - GIS Lessons for You: Comparing Formal and Informal Learning Approaches

High quality teaching materials can be a valuable resource for educators to efficiently teach learners what they may wish to learn; however, if the learners cannot access these materials, then they are not particularly effective. Chapter 7 introduced GIS Lessons for You (GL4U) as an online learning resource based on the findings from the previous chapters that builds on the theoretical foundations presented in the modified TPACK framework (Figure 6.10). The purpose of this learning resource was to teach the GIS concepts, as framed by the Geographic Information Science and Technology (GIS&T) Body of Knowledge (BoK), of Geospatial Data, Analytical Methods and Cartography and Visualisation as these were identified as important concepts from the work in previous chapters (4.1 Google Scholar Analysis, 4.2 Online Survey, 5.1 One-on-One Interviews). Using GL4U, these were then taught through a Context Based Learning (CBL) approach, which was also suggested to be conducive to interdisciplinary learning (2.3 Learning in Interdisciplinary Research). The work in that chapter compared the dimensions of relevant and non-relevant Learning Activity Contexts (LACs), with reference to Rose (2012) and the posed dual axis of CBL and how it applies to LACs, to investigate its role when interdisciplinary researchers learn GIS.

The work with LACs was carried out in a formal/non-formal Learning Environment Context (LEC); again, recognising Rose (2012), the dual axis of CBL also applies to the LEC, which can apply to formal/non-formal and informal LECs. The interplay of the LAC with the LEC is be illustrated in Figure 8.1.

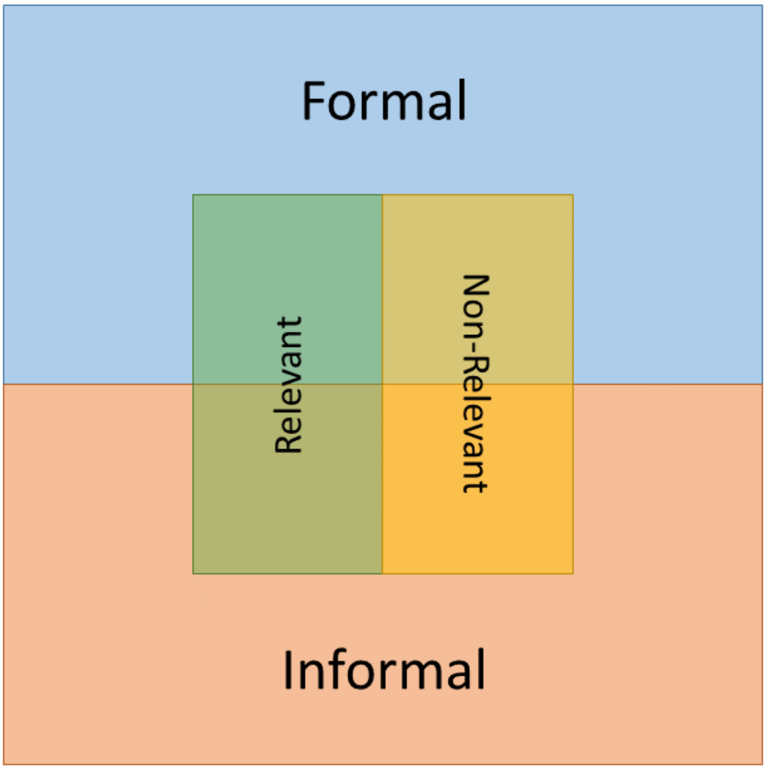


Figure 8.1 Formal and Informal LECs and interplay of Relevant and Non-Relevant LACs

In Chapter 7, the formal LEC and relevant and non-relevant LACs were explored. However, the informal LEC has been recognised as the environment in which many interdisciplinary researchers learn. Therefore, to explore fully the LECs, the research detailed in this chapter will compare the formal and informal environments.

As discussed in previous chapters (4.1 Google Scholar Analysis, 4.2 Online Survey, 5.1 One-on-One Interviews), interdisciplinary researchers use informal learning approaches. This may be because, in comparison, formal/non-formal learning programs and materials may be considered expensive, time-consuming to produce, boring and/or ineffective (Israelite, 2006). However, would that still be the case when more specifically applied? How would a learning approach using materials constructed for a formal/non-formal LEC, such as GL4U, compare to an informal one when interdisciplinary researchers learn GIS? Is a formal/non-formal approach more effective at expediting uptake of learning and confidence in long-term use of GIS?

In order to consider GL4U and CBL with respect to learning GIS in IDR, it is necessary to use and compare GL4U in a formal/non-formal LEC to an informal one in either a real or simulated setting. This was to continue to explore the following research question (also illustrated in Figure 1.3):

- Can a contextually relevant mixed formal (institutionally led)/non-formal (loosely organised) learning resource improve uptake and application of GIS in IDR?

As explained in 7.2 Interdisciplinary Learning Opportunities for GL4U, finding active IDR projects that were interested in learning GIS and using GL4U proved difficult. Therefore, a simulation was held in the form of two workshops – a formal/non-formal one that used GL4U and another one where participants were given the same tasks to do in the GIS without access to GL4U, though they could use the internet to find information, which simulated an informal LEC. The results of these workshops were reviewed to understand how quickly participants were able to complete the tasks in the GIS and their opinion of the perceived effectiveness of the learning approach they used afterwards. This was to see where learners encountered issues with the GIS, how they went about solving them and where they found the resources to do so.

8.1 Methodology

8.1.1 Formal/Informal Learning Workshops – Study Design

To explore the LECs with respect to interdisciplinary researchers learning GIS, with the assistance of volunteers, two three hour learning workshops for GIS were held – a formal learning workshop and an informal learning workshop. The formal learning workshop made use of GL4U, a formal/non-formal LEC resource, with the goal of teaching learners to construct a Story Map – a digital map that combines narrative text, images and multimedia, including video, to tell a story about places, locations or geography (Story Maps, 2018) – in Esri's ArcGIS Online platform. Both not only used ArcGIS Online for the sake of comparability between workshops, but also because of the benefits outlined in Table 7.3. The informal learning workshop aimed to simulate an informal, real-world LEC, where learners might be asked to create a map using existing data as part of an IDR project, but may not necessarily have the background knowledge on how to do so. In this simulation, they were given a task list to complete in ArcGIS Online that was the same as the tasks that were in GL4U, with the final output again being a Story Map. However, the learners in this workshop were not be given access to GL4U and were expected to find any learning materials on their own. The process necessary for obtaining ethics approval, recruiting participants, setting up the workshops and activities during and after them are detailed in Figure 8.2 and will be explained in greater detail in this and the following section.

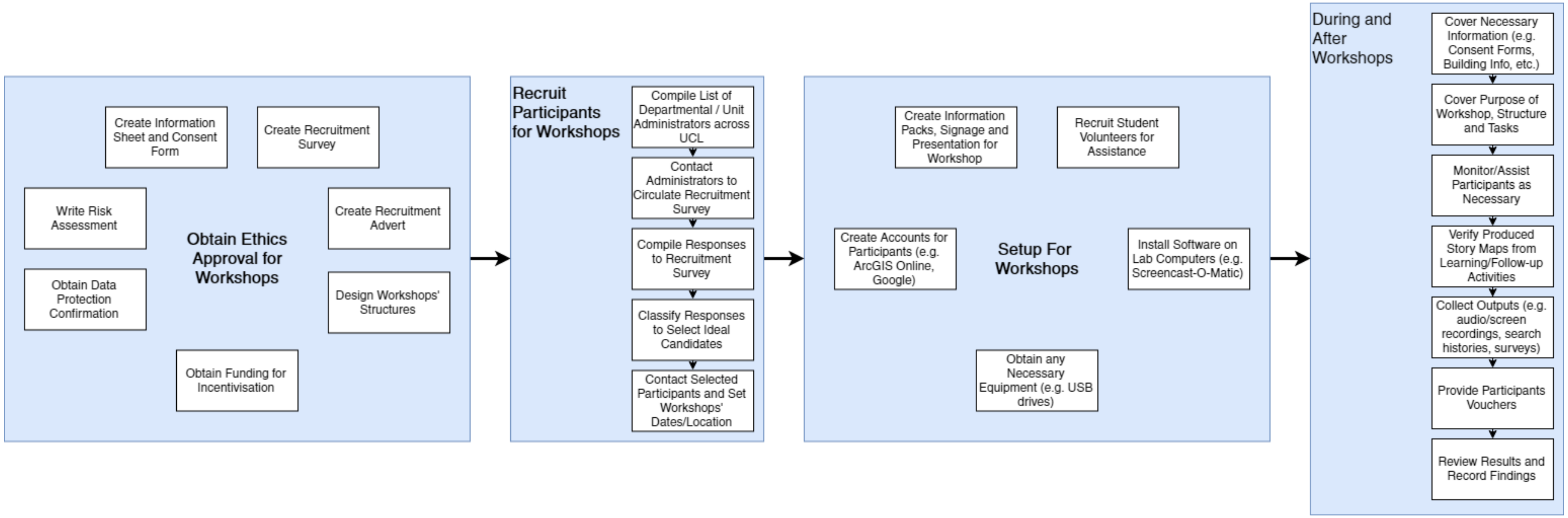


Figure 8.2 Process for Designing and Conducting Workshops

Three hours was decided as the length for the workshops based upon the amount of time it had taken learners to complete the materials in GL4U, as covered in Chapter 7, and to include time for any other pre/post workshop activity work. From the beginning of the workshop, including time for an initial presentation on necessary information and the purpose of this work, participants were given roughly two hours to complete the learning activity tasks and one hour for the follow-up activity.

In order to ensure adequate recruitment of participants for the workshops, given the amount of time needed for them, it was decided to incentivise the study. As those in the informal learning workshop would not be provided similar access to learning materials as participants in the formal one, the informal participants may not achieve the same learning objectives as the formal participants. Therefore, the intrinsic motivation to participate in the informal workshop as an opportunity to learn GIS may be difficult to achieve. Extrinsic motivation, such as monetary incentives, can effectively recruit necessary participants for studies and is a commonly used approach by researchers (Mapstone, Elbourne & Roberts, 2007). To ensure balanced participation in the workshops and remove incentive caused bias, participants in both were incentivised, with each one being paid £30 for three hours of their time.

For the sake of the manageability of the workshops and their costs, it was determined that ten participants per workshop, or 20 in total, was sufficient for the initial explorations of this work. Given the cost for incentivisation for participation, which was £600 in total, various funding streams across UCL and other sectors were investigated; in the end, Esri UK donated the necessary funds as £30 Amazon vouchers. Again, it should be noted that the software for these workshops was chosen prior to Esri UK's agreement to fund them, based on the comparison of platforms (Table 7.3) and to ensure both used the same software.

To simulate potential researchers on an IDR project, participation eligibility was limited to university students, staff and researchers. The workshops were advertised through distributing flyers around UCL, sharing information online via social media networks and emailing departmental administrators around UCL asking them to tell their departments' students about the workshops. To be considered for participation in the workshop, potential participants then needed to complete a survey via UCL's approved survey platform, Opinio, to register their interest.

Questions in the survey allowed background information on potential participants to be gathered (over the age of 18, disciplinary background, IDR experience, GIS experience and interest in learning GIS); a full list of the questions from this survey may be found in

A.6.1 Recruitment Survey Questions and Responses. Based on the responses to the survey, candidates were selected such that the workshops had participants from a variety of disciplinary backgrounds and that those participants were over the age of 18, had prior experience in interdisciplinary research, little/no experience with GIS and were interested in learning GIS, similar to researchers from the preliminary case studies (Chapter 3) and those who piloted GL4U (Chapter 7). Once recruited, times/dates were selected, based on the availability of participants and an appropriate computer lab at UCL, given that both workshops were hosted there. During the workshops, all participants' computer screens were recorded to review their actions and audio recording was carried out to capture any questions that might be asked using Screencast-o-matic; as such, ethics approval was procured, which will be discussed in 8.1.2 Formal/Informal Learning Workshops – Confirmation and Structure. As the GIS to be used (ArcGIS Online) only requires access to the internet and an internet browser, any of the computer labs at UCL could be used; however, it was still necessary to ensure screen/audio recording software could also be installed on the machines. Participants' search histories were also to be captured; therefore, Google accounts were set up for them to use, which saved their search histories for later access. These accounts as well as those for ArcGIS Online were created in advance of the workshops and assigned to participants to minimise setup time and ensure anonymity.

At the beginning of the workshops, a short presentation was given that included necessary administrative information (health and safety information, evacuation procedures, information sheets and consent forms, workshop timetable), what a GIS is and what Story Maps are, the structure of the workshop and closedown activities (saving audio/screen recording, saving search history, completing a follow-up survey). Participants were reassured that completion of the Story Map(s) is not a requirement of the workshop; however, those in the informal learning workshop were requested not to use the lessons from GL4U, which were taken offline to ensure they were not available. In addition, all participants were notified that they must not work together and that the researcher or volunteers may only help with technical issues with the computers/GIS. This ensured that participants could work through any issues they may encounter in the GIS on their own, searching for information online as necessary, to simulate an IDR setting where they may be the only person tasked with and capable of doing the GIS work.

As mentioned earlier, from the beginning of the workshop, including time for the presentation, participants were given roughly two hours to complete the learning activity tasks to leave one hour for a follow-up activity. In the formal learning workshop, this involved selecting the LAC within GL4U that they considered most relevant to their discipline or of interest to them (Water Access in Lima, Disaster Planning in Seattle, Medieval Swansea or Generic [7.4 Accessing Contexts and Lessons in GL4U]) and completing the following lessons:

- 1. Intro to ArcGIS Online
- 2. Adding and Displaying Layers of Information
- 3. Saving and Printing a Map
- 5. Sharing your Content through Story Maps

Tasks were aligned between the formal, using the lessons from GL4U, and informal learning workshops; Table 8.1 shows this as well as the purpose of the tasks – whether they were necessary to familiarise learners with the software or if they were associated with GIS&T BoK KA(s).

Table 8.1 List of tasks to be completed in the workshops with corresponding GL4U lesson noted

LESSON	TASK	PURPOSE
2	Be able to move around and zoom in/out on the map	Cartography and Visualization
3	Change the basemap of the map	Cartography and Visualization
2	Search for Layers and add a layer to the map	Cartography and Visualization; Geospatial Data
2	Add Layer from File to the map • Do this for 2 Shapefiles (ZIP archive containing all shapefile files) and Change Style for both added shapefile layers • Change Symbols to Show Location Only and change the colour (both Fill and Outline)	Cartography and Visualization; Geospatial Data
2	Add Layer from Web to the map • Add A KML File using a URL	Cartography and Visualization; Geospatial Data
2	Add a Map Notes Layer to the map • Edit Map Notes to Add Features and add a point to the map • Give the point a Title, Description, Image URL and Image Link URL	Cartography and Visualization; Geospatial Data; Analytical Methods
3	Save the map you have created • Give it a Title, Tags and a Summary	Software Use
5	Share the map you have created • Share with Everyone (public)	Software Use
5	Create a Web App using the Story Map Series Configurable App • Use the Tabbed layout and ensure the tab has a Legend	Cartography and Visualization
5	Add text and an image to the text box in the Story Map	Cartography and Visualization; Geospatial Data
5	Save the Story Map and View Live version	Software Use

The tasks in Table 8.1 used exact terminology from ArcGIS Online. As found in previous chapters (Chapter 4, Chapter 5, Chapter 7), the meaning of language can be a factor that affects the learning experience. In GL4U, some of the terminology meanings are explained as part of the lessons; however, in an informal learning approach, learners may have to find these meanings on their own. Therefore, the exact words in the interface were used, such that learners could use them to find their meanings, should they not understand them. As had been mentioned by interviewees in 5.1.5 Discussion, when asked to do tasks in a GIS and they did not know or recall how to do them, learners used the GIS terminology and the name of the software package to search for further information. As such, outlining tasks and using associated language, which learners can investigate in this setting, could be considered representative of a real-world example of using GIS in IDR.

In the informal workshops, participants were given all the data and necessary information from the context of precarious structures in Jose Carlos Mariategui in Lima, Peru, and were asked to complete the tasks as listed in the Table 8.1, with the corresponding lesson information removed, as they were not using GL4U. Participants were then asked to note when they started and completed the learning activity, where completion was considered when they saved and completed the Story Map and it had been reviewed to ensure they had completed all the other tasks to create it. If any tasks were missed, participants were asked to go back and do them and the completion time was adjusted accordingly.

After participants completed the learning activity, they were presented with a follow-up activity to complete in roughly one hour, where they were given all the data and necessary information to create another Story Map. The second Story Map for both workshops related to Bombs Dropped on Bloomsbury during World War 2, which was the same follow-up activity used with the Digital Humanities students (discussed in 7.5 Using GL4U in Formal Education with Interdisciplinary Learners). Participants were asked to create this Story Map without referring to any of the learning materials they had just used to create the first Story Map, whether it was GL4U or whatever resources those in the informal learning workshop may have used. Should they be unable to recall how to do a particular task, they were allowed to ask the researcher or volunteer, who provided leading questions to help them try to recall how to do the task, without specifically telling them how to do it. This was to see if they were able to recall GIS concepts and how to use ArcGIS online, based on the memory cues they were able to construct as part of the learning activity. Participants recorded when they started the follow-up activity and when they finished the new Story Map, which was checked to ensure the same tasks from the learning activity were carried out and the completion time adjusted, if necessary.

Afterwards, participants were asked to save and submit their screen and audio recordings, search histories and complete a follow-up survey in Opinio, which was agreed as part of the ethics approval (8.1.2 Formal/Informal Learning Workshops – Confirmation and Structure). Questions in the follow-up survey related to students' understanding of and continued motivation to use GIS, the relevance of GIS concepts and information gathering methods, what they were able to complete in the workshop and the perceived effectiveness of the workshop's learning approach. A full list of the survey questions can be found in A.6.2 Workshop Follow-up Survey Questions and Responses.

After the workshops, all screen recordings were watched and a stopwatch was used to record the amount of time it took for participants to complete tasks (discussed in 8.3.1 Screen Recordings and 8.4.1 Screen Recordings). This was determined based upon mouse movements, selections and clicks in the GIS interface. Start time for both the learning and follow-up activities were noted based upon the participant loading a new map or starting to interact with the documentation for the activity. For the final task, the Story Map was considered complete at the time when the user clicked the Save button, rather than when it had been noted that they compiled all the necessary elements for the Story Map from the screen recording. With regard to the other tasks, a task was considered complete when the action was performed, even if the details of the execution were not as directed (e.g. adding a different layer, text or image than requested, using a different web map app template than requested, etc.). A second stopwatch was also used to record the amount of time participants spent on GL4U or other materials, as opposed to time spent on ArcGIS Online. This was determined by when a participant's screen did not show ArcGIS online as the active window or, if they had two windows side by side, when their mouse was positioned over the window with GL4U or other materials.

Using the recorded completion times, Box plots were used to display data as they are a well-known simple display of the five number summary (lower extreme, lower quartile, median [middle value of the dataset], upper quartile, upper extreme) (Laurikkala et al, 2000). Quartiles are a division of four quantiles, which is a statistical method used to divide ranges of data into equal sized groups. The Inter-Quartile Range (IQR) is the range that encompasses 50% of the data, which is between the lower and upper quartile. Box plots, and the representation of the median and IQR, are also most suitable for exploring both symmetric and skewed values as well as identifying infrequent ones (Laurikkala et al, 2000) and as such were used to represent the outputs from them work.

Search histories were reviewed by compiling browser history data for each participant and isolating internet searches made. From there, as the search performed is part of the URL, these can then be examined to identify the exact search terms used for the search. With regard to the follow-up survey results, these were tabulated to compare responses and derive any patterns that may have emerged from the workshop.

8.1.2 Formal/Informal Learning Workshops – Confirmation and Structure

Based on this design, an application was made in November 2016 to the UCL Research Ethics Committee for Chair's Approval for the study, as it was to involve people but does not deal with those from vulnerable communities or sensitive information. This application also included the necessary risk assessment information, approved data protection application and drafts of all associated information with the study (surveys, flyers for advertising, information and consent sheets). Approval was received in December 2016 and advertising for participants began shortly thereafter via social media and departmental administrative contacts across UCL (81 in total), which was derived from accessing every UCL department's website and recording the listed email address. In January 2017, responses to the recruitment survey were reviewed and, in total, 158 were received; this was even before flyers had been distributed across the university. As this was considered a sufficient number of responses, the flyers did not need to be used, further advertising efforts were halted and potential computer lab time slots were booked in January and February 2017.

On the day, the student volunteer, one for each workshop, was supplied with a list of participants and instructed to meet them at the agreed meeting point. Meanwhile, the computers, which had previously had audio/screen recording software installed on them, were prepared for participants. Workshop information packets were supplied at each workstation (an example has been provided in A.6.3 Workshop Information (Presentation, Signed Consent Sheets, Information Packs, Screen Recordings, Search Histories)) with the individuals credentials, should they be needed (name, Google user name, password, ArcGIS Online user name, password), and all the necessary information for the workshop (parameters, timetable, task list, an area to make notes [if necessary]). Once all participants had arrived, the volunteer then brought them all up to the lab. A sign was put on the outside of the lab door to notify of the audio recording in progress to ensure only those who had signed the consent sheet (see A.6.3 Workshop Information (Presentation, Signed Consent Sheets, Information Packs, Screen

Recordings, Search Histories)) were in the lab, and the beginning presentation was given. Before proceeding, participants were asked to review the information sheet and sign the consent form; any who no longer wished to participate in the workshop needed to identify themselves at that point, as the workshop could not progress without the consent forms being signed and returned. As all participants from both workshops had agreed to consent and signed the forms, the learning activity commenced after the forms were collected.

The researcher and volunteer then monitored participants in the workshops and answered questions as necessary. The tasks participants were to do in the GIS for the learning and follow-up activities, as well as the overall structure for the workshops has been detailed in 8.1.1 Formal/Informal Learning Workshops – Study Design. After completing the learning activity, the researcher and volunteer checked the Story Maps for the completion of all necessary tasks and the same was completed for the follow-up activity Story Maps. After those were complete, the researcher and volunteer checked to make sure participants had completed the follow-up survey and helped participants to save their audio/screen recordings as well as search histories. All required files were saved onto the provided USB drives, which were then collected and information was copied off them onto a central, secure computer, in compliance with the UK Data Protection Act 1998, as required by the completed ethics application. Once all necessities were complete, the participants were each given a £30 Amazon voucher.

8.2 Results – Participant Recruitment Survey and Selection

The results from the recruitment survey itself revealed some interesting information about the disciplines of the people who may be interested in learning GIS. They identified as being from 48 different disciplines, which are listed in Table 8.2.

Table 8.2 Unique disciplines of respondents to recruitment survey

Disciplines	Number of Respondents
Animal Behaviour and Welfare	1
Anthropology	2
Archives and Records Management	2
Art History & Computer Science	1
Art History & Digital Humanities	1
Biochemistry	2
Biology	1
Business and Publishing	1
Chemical Engineering	2
Chemistry	2
Computer Science	11
Economics	1
Electronic and Electrical Engineering	12
Engineering	3
English Literature & Physics	1
Environmental Science	1
Epidemiology	6
Fine Art	4
Geography	1
Global Health and Development	1
Health & Medicine	7
Heritage Science	3
History	1
History & Sociology	1
Human Computer Interaction	3
Humanities	1
Jewish Studies	2
Language Studies	1
Life Sciences	1
Mathematics	2
Mathematics & Computer Science	2
Mechanical Engineering	1
Medicine	1
Neuroscience	1
Nursing	1

Pharmaceutical Sciences	27
Philosophy	1
Physics	26
Physics & Computer Science	1
Political Science & Sociology	1
Political Science & Statistics	1
Psychology	4
Public Health	1
Robotics	1
Science and Technology Studies	5
Social Sciences	3
Statistics	2
Zoology	1
Total	158

Other information worth noting from recruitment survey respondents was as follows:

- All (100%) were over the age of 18
- 61 respondents (39%) had previous experience with interdisciplinary research, while the other 97 (61%) did not
- With respect to experience with GIS, 148 respondents (94%) identified has having no experience at all, 8 as having very little experience (5%) and 2 as having basic experience (1%); no respondents had intermediate or advanced experience with GIS.
- With regard to interest in learning GIS, 42 were highly interested (27%), 54 were very interested (34%), 36 were moderately interested (23%), 24 were somewhat interested (15%) and 2 were not interested at all (1%)

With the responses received, based on the information given, respondents were categorised into 5 different tiers around having the preferred characteristics for the workshops:

- Tier 1: previous experience with IDR, no experience with GIS, highly interested in learning GIS
- Tier 2: previous experience with IDR, little/no experience with GIS, highly/very interested in learning GIS
- Tier 3: no previous experience with IDR, little/no experience with GIS, very/moderately interested in learning GIS

- Tier 4: no previous experience with IDR, little experience with GIS, moderately/somewhat interested in learning GIS
- Tier 5: no previous experience with IDR, little/basic experience with GIS, somewhat/not at all interested in learning GIS

All respondents were contacted to let them know whether they had been accepted, put on a waitlist or rejected. Those who had been accepted were largely from Tier 1, otherwise from Tier 2, if there were multiple people from the same discipline, in order to have as wide of a variety of disciplinary backgrounds in the workshops. These potential participants were given the dates/times for which the computer lab was booked and identified which ones they could or could not attend. From there, the dates for the workshops were set for 27 January 2017 (formal learning workshop) and 06 February 2017 (informal learning workshop). The participants in the workshop on 27 January 2017 were randomly chosen to take the formal learning approach, and so those on 06 February 2017 would be doing informal learning. Prior to the workshops, the necessary Google and ArcGIS Online accounts were created, and the lab was set up with the required screen and audio recording software; USB drives were also procured to transfer the resulting files on/off the lab computers, which included all necessary data for the workshops. Two student volunteers, both from the UCL Department of Civil, Environmental and Geomatic Engineering, were also recruited to help with the workshops, who were briefed on the workshop format and what may be required from them to assist the researcher and learners. From the potential participants, some had to drop out, and so those from the waitlist were contacted to replace them. In total, 9 participants attended the formal learning workshop (Table 8.3) and 11 the informal one (Table 8.4) (1 extra was invited to the informal one as there was an extra £30 Amazon voucher available that was not used for the formal learning workshop. This was to gather as many outputs for analysis from the workshops as possible with the given funds).

Table 8.3 Participants from the formal learning workshop

ID	Home Discipline	Interdisciplinary Experience	GIS Experience	Level of Interest in Learning GIS	Tier
Formal1	Psychology	Yes	No experience at all	Highly interested	1
Formal2	Neuroscience	Yes	No experience at all	Highly interested	1
Formal3	Chemistry	Yes	No experience at all	Moderately interested	1
Formal4	Physics	Yes	Very little experience	Very interested	1
Formal5	Pharmaceutical Sciences	Yes	No experience at all	Highly interested	1
Formal6	Statistics	Yes	Very little experience	Highly interested	1
Formal7	Nursing	Yes	Very little experience	Very interested	1
Formal8	Political Science & Statistics	Yes	No experience at all	Highly interested	1
Formal9	Fine Art	Yes	No experience at all	Moderately interested	2

Table 8.4 Participants in the informal learning workshop

ID	Home Discipline	Interdisciplinary Experience	GIS Experience	Level of Interest in Learning GIS	Tier
Informal1	Zoology	Yes	Very little experience	Moderately interested	1
Informal2	Epidemiology	Yes	No experience at all	Highly interested	1
Informal3	Human Computer Interaction	Yes	No experience at all	Highly interested	1
Informal4	Electronic and Electrical Engineering	Yes	No experience at all	Very interested	1
Informal5	Heritage Science	Yes	No experience at all	Very interested	1
Informal6	Art History & Digital Humanities	Yes	No experience at all	Highly interested	1
Informal7	Public Health	Yes	No experience at all	Highly interested	1
Informal8	Anthropology	Yes	No experience at all	Very interested	2
Informal9	Health & Medicine	Yes	No experience at all	Very interested	2
Informal10	Health & Medicine	Yes	No experience at all	Highly interested	2
Informal11	Political Science & Sociology	Yes	No experience at all	Very interested	2

8.3 Formal Learning Workshop

8.3.1 Screen Recordings

An analysis was carried out on the time it took participants to complete the tasks in the workshop. Each of the participants' screen recordings[9] were reviewed and the time when

[9] A sample screen recording from this workshop may be found on the USB Drive, as detailed in A.6.3 Workshop Information (Presentation, Signed Consent Sheets, Information Packs, Screen Recordings, Search Histories).

they completed the tasks was noted. The researcher watched each participant's screen recording and, using a stopwatch, noted the exact time from when they began working on the learning activity to when the participant completed a task. After the task completion time was recorded, the stopwatch was reset and used to begin timing for the next task. This process was followed for all tasks in both the learning and follow-up activities. A screenshot from one of the recordings may be seen in Figure 8.3.

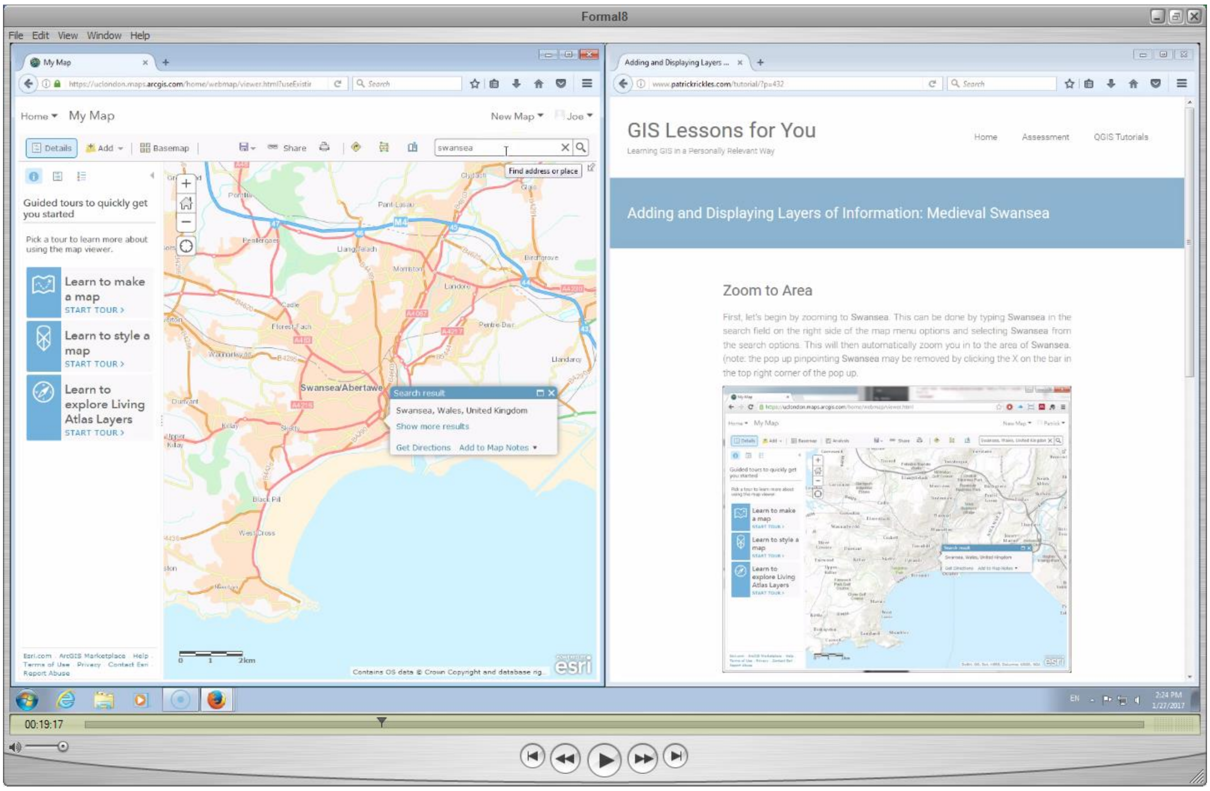


Figure 8.3 Screen Recording example from Formal Workshop

In total, for the formal workshop, 11h:21m:35s of recordings were reviewed for the learning activity and 1h:56m:02s for the follow-up activity. Task completion times for the learning activity are shown in the chart in Figure 8.4 and for the follow-up activity in Figure 8.5.

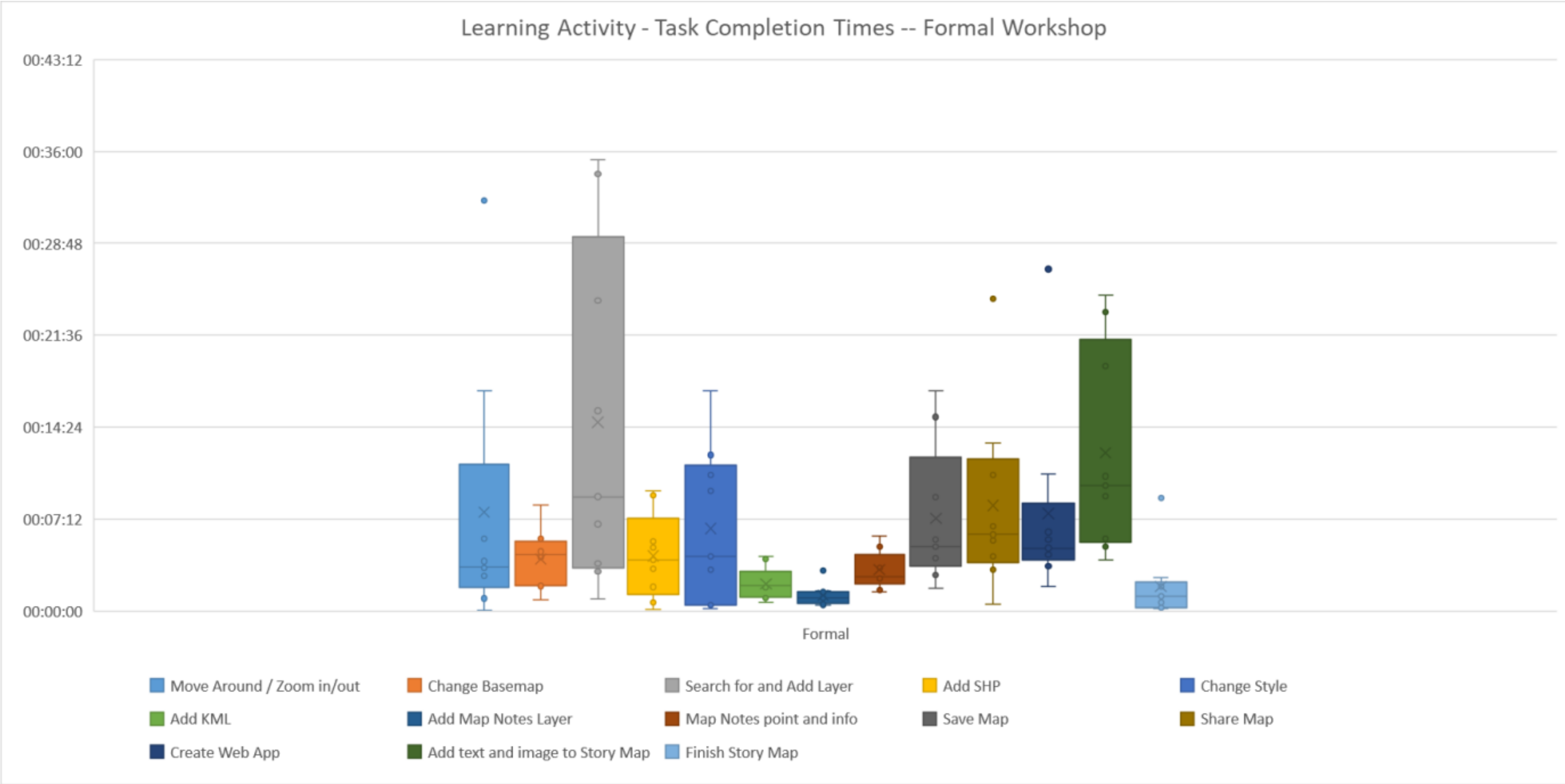


Figure 8.4 Task completion times chart for the Learning Activity – Formal Workshop

To clarify, important measures from the chart in Figure 8.4 are listed in Table 8.5.

Table 8.5 Task completion times table (Median and Inter-Quartile Range) associated with Figure 8.4 for the Learning Activity – Formal Workshop

Task	Median	Inter-Quartile Range
Move Around / Zoom in/out	00h:03m:26s	00h:01m:53s – 00h:11m:29s
Change Basemap	00h:04m:27s	00h:02m:01s – 00h:05m:29s
Search for and Add Layer	00h:08m:58s	00h:03m:25s – 00h:29m:17s
Add SHP	00h:04m:00s	00h:01m:17s – 00h:07m:17s
Change Style	00h:04m:19s	00h:00m:31s – 00h:11m:26s
Add KML	00h:01m:59s	00h:01m:06s – 00h:03m:07s
Add Map Notes Layer	00h:01m:02s	00h:00m:36s – 00h:01m:32s
Map Notes point and info	00h:02m:44s	00h:02m:08s – 00h:04m:26s
Save Map	00h:05m:03s	00h:03m:30s – 00h:12m:04s
Share Map	00h:06m:00s	00h:03m:48s – 00h:11m:54s
Create Web App	00h:04m:57s	00h:04m:00s – 00h:08m:29s
Add text and image to Story Map	00h:09m:51s	00h:05m:23s – 00h:21m:18s
Finish Story Map	00h:01m:09s	00h:00m:17s – 00h:02m:16s

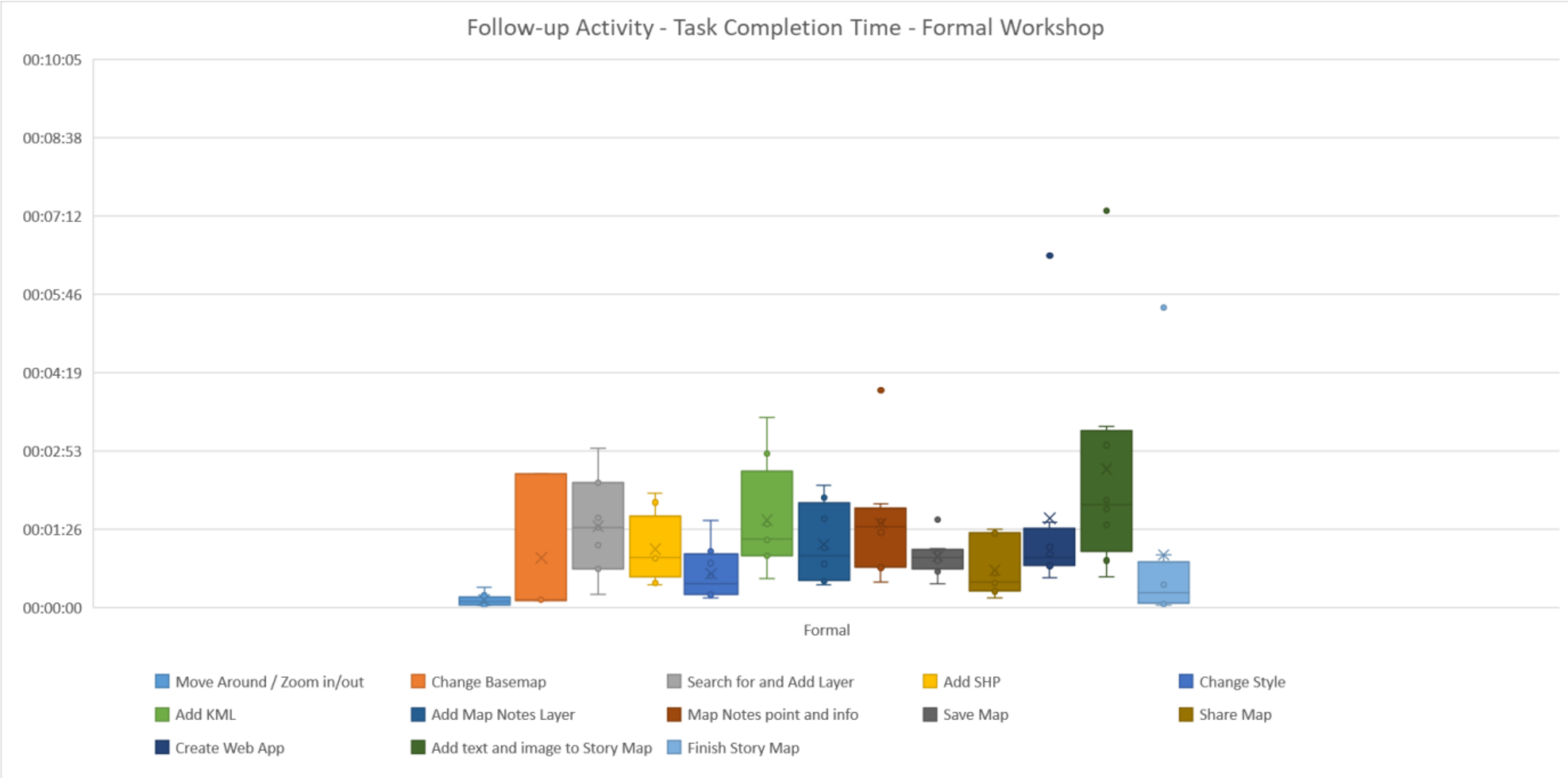


Figure 8.5 Task Completion for the Follow-up Activity – Formal Workshop

Again, to clarify, important measures from the chart in Figure 8.5 are listed in Table 8.6.

Table 8.6 Task completion times table (Median and Inter-Quartile Range) associated with Figure 8.5 for the Follow-up Activity – Formal Workshop

Task	Median	Inter-Quartile Range
Move Around / Zoom in/out	00h:00m:07s	00h:00m:03s – 00h:00m:12s
Change Basemap	00h:00m:09s	00h:00m:08s – 00h:02m:27s
Search for and Add Layer	00h:01m:28s	00h:00m:43s – 00h:02m:18s
Add SHP	00h:00m:55s	00h:00m:34s – 00h:01m:41s
Change Style	00h:00m:26s	00h:00m:14s – 00h:00m:59s
Add KML	00h:01m:16s	00h:00s:57m – 00h:02m:31s
Add Map Notes Layer	00h:00m:57s	00h:00m:30s – 00h:01m:55s
Map Notes point and info	00h:01m:29s	00h:00m:44s – 00h:01m:49s
Save Map	00h:00m:55s	00h:00m:43s – 00h:01m:04s
Share Map	00h:00m:28s	00h:00m:18s – 00h:01m:22s
Create Web App	00h:00m:55s	00h:00m:47s – 00h:01m:27s
Add text and image to Story Map	00h:01m:54s	00h:01m:02s – 00h:03m:15s
Finish Story Map	00h:00m:16s	00h:00m:05s – 00h:00m:51s

Outside of observing the tasks participants were to do in the GIS, other behaviours and patterns that were exhibited were recorded to identify common issues or trends. A full list of these is available in A.6.4 Additional Workshop Findings; however, those worth highlighting are as follows:

- All 9 participants (100%) encountered some usability issues with ArcGIS online (e.g. glitch/technical issue, reloading and losing unsaved progress, difficulties adding information, etc.)
- 1 participant (11%) selected the “Take a Map Tour” option that was initially available to learn about the map functionality, though they did not follow it all the way through
- 1 participant (11%) created the Story Map from the Story Maps website which was discovered as the result of a search, rather than through the ArcGIS Online interface they had been working in
- 5 participants (56%) asked the researcher or volunteer a question (details of questions asked are in A.6.4 Additional Workshop Findings)

8.3.2 Search Histories

Participants’ search histories were reviewed by downloading the raw data from the browser (an example of which can be seen in Figure 8.6, with full details in A.6.3 Workshop Information (Presentation, Signed Consent Sheets, Information Packs, Screen Recordings, Search Histories)) and then formatting and importing it into Excel. The individual URLs were analysed to identify what the pages were and if they were the result of searches performed (based on the recorded “Visited from” information). As the searches and keywords used to perform them were of interest, these were tabulated and categorised, based on the purpose of the search. The categories used for these were as follows:

- GIS Task: Searches to find out how to do a task in the GIS
- Issue: Searches to find information on how to circumnavigate an issue in the GIS
- General Technology: Searches for information on non-GIS related technology
- Browse: Searches for information on GIS related technology
- Context: Searches associated with finding information on the context related to the tasks

```
==================================================
URL               : http://doc.arcgis.com/en/arcgis-online/
Title             : ArcGIS Online Help | ArcGIS
Visit Time        : 1/27/2017 3:00:20 PM
Visit Count       : 1
Visited From      :
Web Browser       : Firefox
User Profile      : ucespri
Browser Profile   : er462ws4.default
URL Length        : 39
Typed Count       :
==================================================

==================================================
URL               : http://doc.arcgis.com/search/?q=can%27t%20zoom
%20in&collection=help&product=arcgis-online&language=en
Title             : Search Result | ArcGIS
Visit Time        : 1/27/2017 3:00:30 PM
Visit Count       : 1
Visited From      : http://doc.arcgis.com/en/arcgis-online/
Web Browser       : Firefox
User Profile      : ucespri
Browser Profile   : er462ws4.default
URL Length        : 101
Typed Count       :
==================================================
```

Figure 8.6 *Raw data example from participant's recorded search history*

The results from analysing and categorising the search history data from workshop participants is listed in Table 8.7.

Table 8.7 Internet searches made [6] by participants [9] in the Formal Learning Workshop

ID	Search Terms	Category
Formal2	ArcGIS changing outline on polygon but nothing happens	GIS Task
Formal2	how long before i can login to GIS after invalid attempts	Issue
Formal5	how do you uncompress a zip file	General Technology
Formal6	ArcGIS Online	Browse
Formal9	1850s Historic Ordnance Survey map of Swansea	Context
Formal9	can't zoom in	Issue

From all participants in this workshop, searches were made by 4 of the 9 participants (44%), whereas the other 5 participants (56%) performed no searches. Of the 6 searches that were made in total, 2 of them are associated with issues with the GIS on logging in and navigating around the map; the search for ArcGIS Online was to browse to the GIS interface; the one on the historic map was to explore the contextual information from one of the lessons; and another for information on general technology on how to unzip a file. Only one search was made for information on how to do a GIS task (changing symbology).

8.3.3 Follow-up Survey

The results from the follow up survey were reviewed by downloading the results from Opinio and tabulating the response data in Excel. This was to not only derive the percentages associated with responses, but to also investigate participants' answers to open text questions to identify commonalities or diverging opinions around specific topics. It was found in the survey that all 9 participants (100%) felt that they were able to build a basic understanding of GIS. One participant noted:

> *"I found the learning part took me quite a while but it probably had to do with my* reading abilities and I was scared to leave anything behind but actually creating *the bombing map was actually pretty straightforward after the slow learning."* (Formal3)

From these participants, 3 (33%) felt extremely confident that they could reproduce a Story Map after the workshop, 3 (33%) felt highly confident, 2 (22%) felt moderately confidently and 1 (11%) participant felt somewhat confident. When asked how motivated they were to continue to use GIS, 1 participant was extremely motivated (11%), 2 participants were highly motivated (22%) and 6 participants were moderately motivated (67%). Reflecting on this, one participant stated:

> *"It has motivated me to consider this method of data communication, as it's* actually so easy to do – *I wasn't aware that it was that easy to do something like* th*is, and it's a good way of showing off a combination of different geospatial data sources. So yes, I will definitely consider how I can use it in future."* (Formal4)

When asked about the GIS&T BoK KAs, all 9 participants (100%) felt Analytical Methods, Cartography and Visualisation, and Data Manipulation were relevant; 7 participants (78%) felt Conceptual Foundations was relevant; 6 participants (67%) felt Data Modeling and Geospatial Data were relevant; 5 participants (56%) felt GIS&T and Society was relevant; 4 participants (44%) felt Geocomputation was relevant; 3 participants (33%) felt Organizational and Institutional Aspects was relevant; and 2 participants (22%) felt Design Aspects was relevant (Figure 8.7). Commenting on these topics, participants said the following:

> *"I think there is a lot you can do with GIS without going too deep into the storage* of the information, *etc."* (Formal4)

> *"… I'm not as interested in the guts of GIS itself, more just as a tool for cataloguing and mapping my own stuff."* (Formal9)

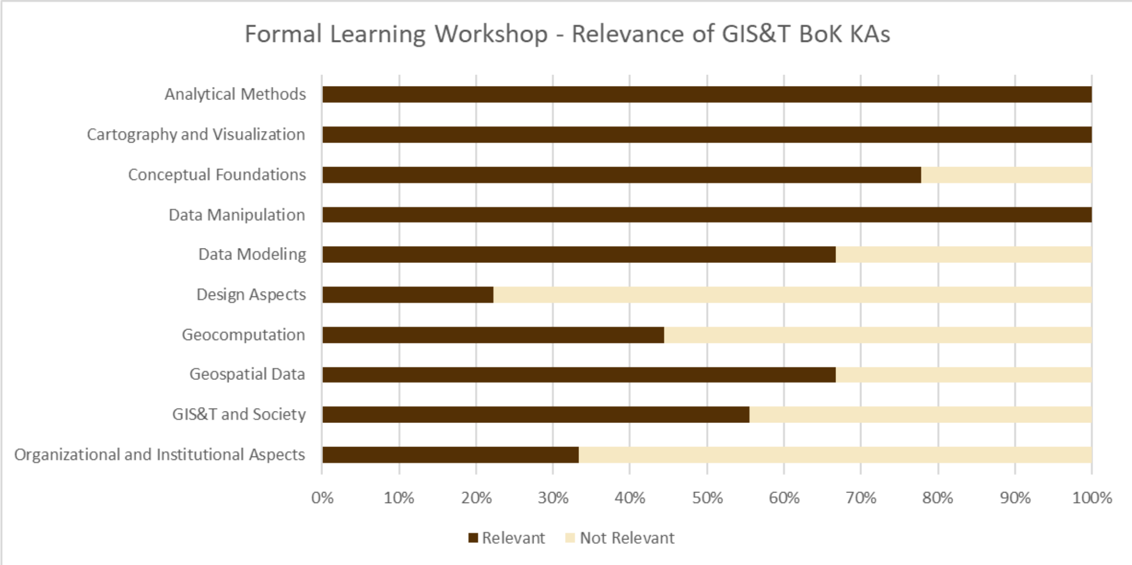


Figure 8.7 *Formal workshop participants' perception of relevance of GIS&T BoK KAs from follow up survey*

With regard to the perceived effectiveness of learning resources that may have been available (Figure 8.8), Follow a Tutorial was considered very effective by 5 participants (56%) or effective by 1 participant (11%); 1 participant considered it not effective (11%) and 2 participants (22%) considered it not applicable. Ask a more experienced person was considered very effective by 3 participants (33%) or effective by 2 participants (22%); no participants considered this to be not effective and 4 participants (55%) considered this to be not applicable. An internet search was considered very effective by 1 participant (11%), effective by 1 participant (11%) and not effective by 1 participant (11%); the rest of the 6 participants (67%) considered it not applicable. 1 participant (11%) believed post on a forum was very effective; the other 8 participants (89%) considered it to be not applicable. Finally, all 9 participants (100%) believed the software help manual and watch a video were not applicable.

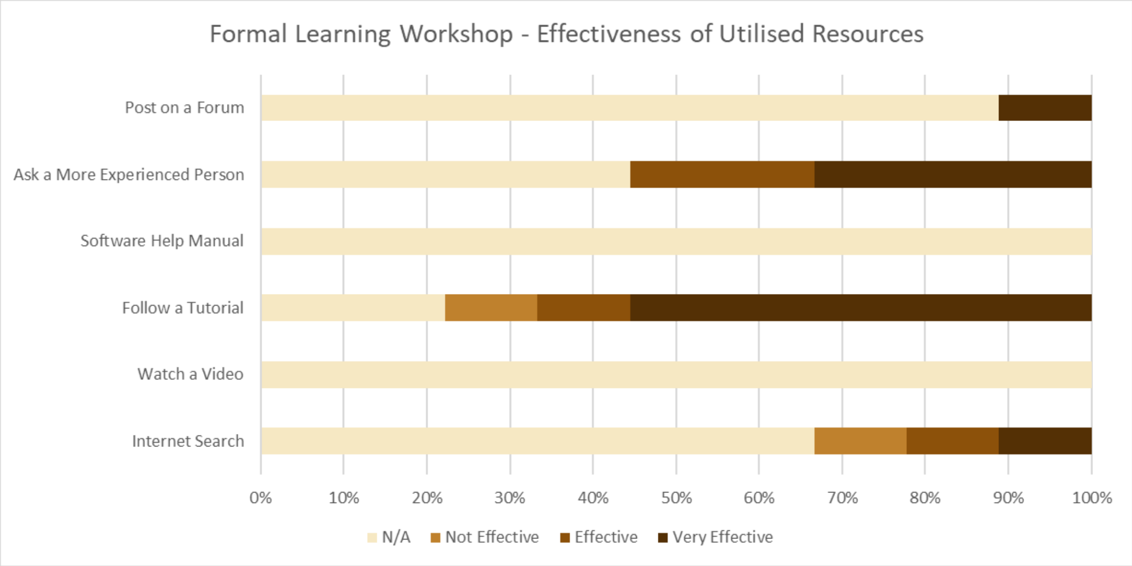


Figure 8.8 *Formal workshop participants' perception of the effectiveness of learning resources from the follow up survey*

8.4 Informal Learning Workshop

8.4.1 Screen Recordings

An analysis was carried out, similar to that of the formal workshop (8.3.1 Screen Recordings), on the time it took participants to complete the tasks in the workshop. Each of the participants' screen recordings were reviewed and the time when they completed the tasks was noted. Again, this was completed by using a stopwatch to note the exact time from when they began working on the learning activity to when the participant completed a task and then the stopwatch was reset to begin timing for the next task. This process was followed for all tasks in both the learning and follow-up activities. A screenshot from one of the recordings may be seen in Figure 8.9.

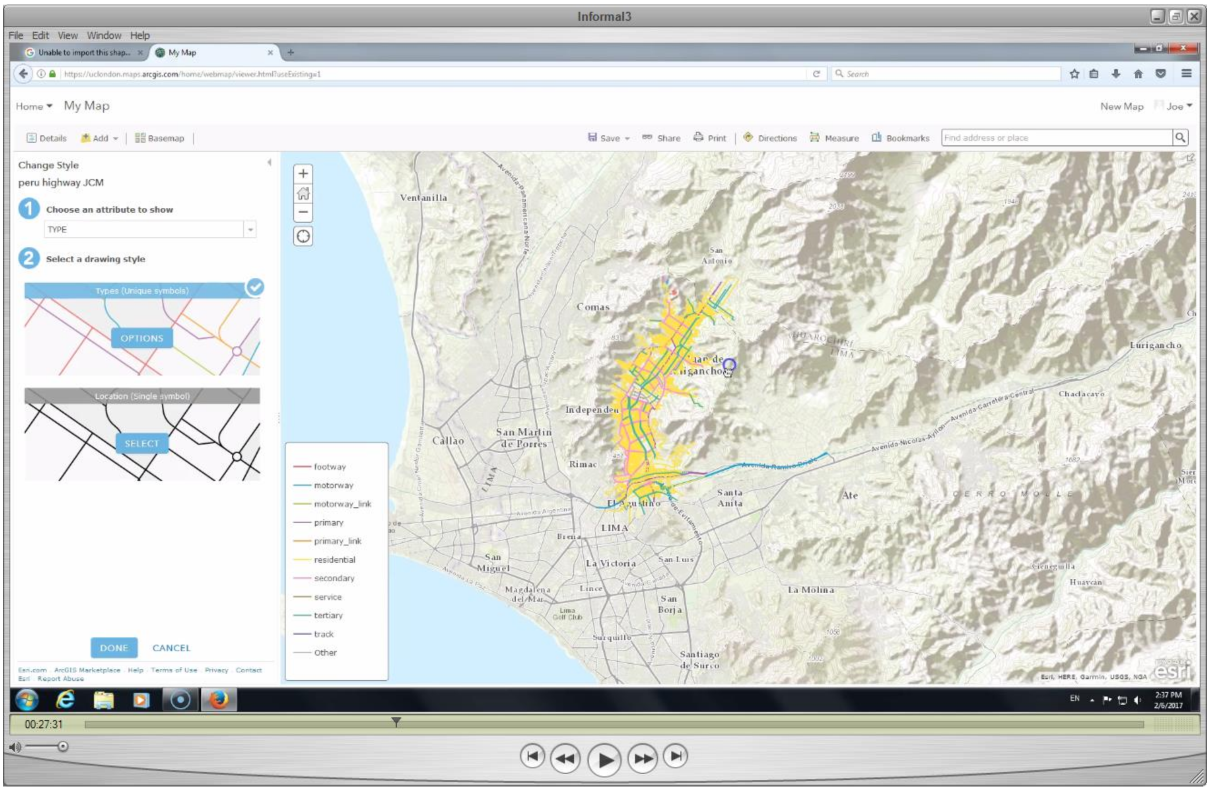


Figure 8.9 Screen Recording example from Informal Workshop

In total, for the informal workshop, 9h:40m:14s of recordings were reviewed for the learning activity and 2h:56m:46s for the follow-up activity. Task completion times for the learning activity are shown in the chart in Figure 8.10 and for the follow-up activity in Figure 8.11.

Figure 8.10 Task completion times chart for the Learning Activity – Informal Workshop

To clarify, important measures from the chart in Figure 8.10 are listed in Table 8.8.

Table 8.8 Task completion times table (Median and Inter-Quartile Range) associated with Figure 8.9 for the Learning Activity – Informal Workshop

Task	Median	Inter-Quartile Range
Move Around / Zoom in/out	00h:00m:19s	00h:00m:09s – 00h:01m:56s
Change Basemap	00h:01m:15s	00h:00m:36s – 00h:04m:00s
Search for and Add Layer	00h:01m:58s	00h:00m:57s – 00h:02m:58s
Add SHP	00h:02m:49s	00h:01m:07s – 00h:08m:22s
Change Style	00h:01m:32s	00h:00m:19s – 00h:02m:56s
Add KML	00h:05m:55s	00h:02m:31s – 00h:12m:11s
Add Map Notes Layer	00h:06m:15s	00h:02m:11s – 00h:10m:02s
Map Notes point and info	00h:02m:33s	00h:01m:15s – 00h:06m:35s
Save Map	00h:01m:50s	00h:01m:08s – 00h:03m:40s
Share Map	00h:00m:28s	00h:00m:14s – 00h:02m:44s
Create Web App	00h:03m:23s	00h:02m:05s – 00h:05m:12s
Add text and image to Story Map	00h:04m:31s	00h:02m:48s – 00h:10m:02s
Finish Story Map	00h:03m:45s	00h:00m:28s – 00h:13m:24s

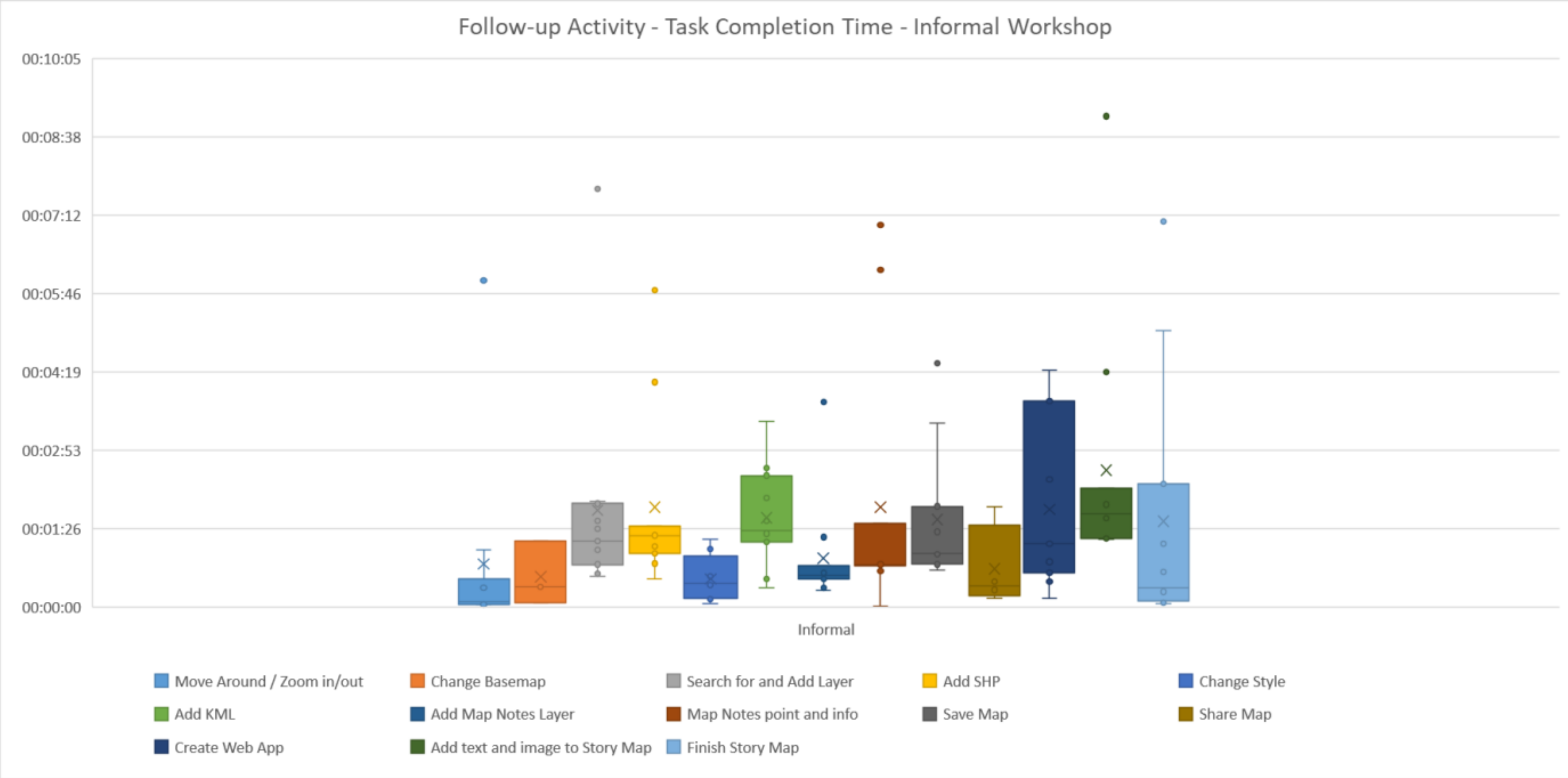


Figure 8.11 Task completion times chart for the Follow-up Activity – Informal Workshop

Again, to clarify, important measure from the chart in Figure 8.10 are listed in Table 8.9.

Table 8.9 Task completion times table (Median and Inter-Quartile Range) associated with Figure 8.10 for the Follow-up Activity – Informal Workshop

Task	Median	Inter-Quartile Range
Move Around / Zoom in/out	00h:00m:06s	00h:00m:03s – 00h:00m:31s
Change Basemap	00h:00m:22s	00h:00m:05s – 00h:01m:13s
Search for and Add Layer	00h:01m:13s	00h:00m:47s – 00h:01m:54s
Add SHP	00h:01m:19s	00h:00m:59s – 00h:01m:29s
Change Style	00h:00m:26s	00h:00m:09s – 00h:00m:56s
Add KML	00h:01m:24s	00h:01m:12s – 00h:02m:25s
Add Map Notes Layer	00h:00m:35s	00h:00m:31s – 00h:00m:46s
Map Notes point and info	00h:00m:47s	00h:00m:46s – 00h:01m:32s
Save Map	00h:00m:59s	00h:00m:48s – 00h:01m:51s
Share Map	00h:00m:23s	00h:00m:12s – 00h:01m:30s
Create Web App	00h:01m:10s	00h:00m:38s – 00h:03m:47s
Add text and image to Story Map	00h:01m:43s	00h:01m:16s – 00h:02m:11s
Finish Story Map	00h:00m:21s	00h:00m:07s – 00h:02m:16s

Outside of observing the tasks participants were to do in the GIS, other behaviours and patterns that were exhibited were recorded to identify common issues or trends. A full list of these is available in A.6.4 Additional Workshop Findings; however, those worth highlighting are as follows:

- All 11 participants (100%) had some usability issues with ArcGIS online (e.g. glitch/technical issue, reloading and losing unsaved progress, difficulties adding information, etc.)
- 3 participants (27%) had selected the “Take a Map Tour” option that was initially available to learn about the map functionality, though they did not follow it all the way through
- 8 participants (73%) created the Story Map from the Story Maps website which was discovered as the result of a search, rather than through the ArcGIS Online interface they had been working in
- 7 participants (64%) asked the researcher or volunteer a question (details of questions asked are in A.6.4 Additional Workshop Findings)

8.4.2 Search Histories

Participants’ search histories were reviewed in a similar fashion to those of the formal workshop (8.3.2 Search Histories), in that the raw data were downloaded from the browser, formatted and imported into Excel and searches performed were categorised as GIS Task, Issue, General Technology, Browse or Context. The results from analysing and categorising the search history data from workshop participants are listed in Table 8.10.

Table 8.10 Internet searches made [53] by participants [11] in the Informal Learning Workshop

ID	Search Terms	Category
Informal8	add image to map notes point	GIS Task
Informal8	add layer through KML	GIS Task
Informal8	adding layers ArcGIS	GIS Task
Informal8	Story Map series configurable app	GIS Task
Informal1	change to tabbed layout GIS	GIS Task
Informal1	create web app GIS	GIS Task
Informal1	GIS add map notes	GIS Task
Informal1	GIS change symbol to show location only	GIS Task
Informal1	Google Maps	Browse
Informal1	tabbed layout Story Map	GIS Task
Informal3	example KML file	GIS Task
Informal3	example KML URL	GIS Task
Informal3	KML File	GIS Task
Informal3	KML URL	GIS Task
Informal3	Unable to import this shapefile. (The operation was attempted on an empty geometry.)	Issue

Informal4	EDINA	Context
Informal4	KML File	GIS Task
Informal4	nowhere far away Peru	Context
Informal4	Story Map series configurable app	GIS Task
Informal9	area Juan Carlos Mariategui Lima	Context
Informal9	Story Map Series	GIS Task
Informal9	Story Map series configurable app	GIS Task
Informal5	ArcGIS adding saved map	GIS Task
Informal6	how to create a map point ArcGIS URL link	GIS Task
Informal6	how to create a Story Map	GIS Task
Informal6	how to create map point ArcGIS	GIS Task
Informal6	learn GIS follow up	Browse
Informal6	PNG file	General Technology
Informal6	polyline shapefile how to add	GIS Task
Informal6	tabbed layout	GIS Task
Informal10	ArcGIS Story Map builder	GIS Task
Informal10	Chile layers for ArcGIS	Context
Informal10	collapsed structure in Juan Carlos Mariategui Lima	Context
Informal10	configurable web app (Story Map tabbed layout)	GIS Task
Informal10	Story Maps series configurable app	GIS Task
Informal7	create a new web app ArcGIS	GIS Task
Informal7	KML file	GIS Task
Informal7	KML file layer	GIS Task
Informal7	KML file layer download free	GIS Task
Informal7	KML layer download free	GIS Task
Informal7	London map	Context
Informal7	Story Map tabbed layout	GIS Task
Informal7	web layer URL ArcGIS	GIS Task
Informal11	ArcGIS layer online	GIS Task
Informal11	big intersection	Context
Informal11	find ArcGIS KML layers online	GIS Task
Informal11	find ArcGIS layers online	GIS Task
Informal11	find ArcGIS maps online	GIS Task
Informal11	how to find a KML layer on the web	GIS Task
Informal11	KML layer lima	GIS Task
Informal11	maps of Lima	Context
Informal11	Shapefiles	GIS Task
Informal11	Story Map series configurable app	GIS Task

From all participants in this workshop, 10 of the 11 participants (91%) made internet searches and one participant performed no searches at all. Of the 53 searches that were made in total, one was associated with an issue with the GIS on importing a shapefile; 2 searches were to browse to the follow up activity for the workshop and Google Maps; 8 searches were performed to find contextual information on Lima, Peru and other types of information; and one search was performed on general technology for information on Portable Network Graphics (PNG) files. 41 of the 53 searches (77%) were on how to do tasks within the GIS.

8.4.3 Follow-up Survey

Similar to the formal one (8.3.3 Follow-up Survey), the results from the follow up survey for the informal workshop were reviewed by downloading the response data from Opinio and tabulating it in Excel to identify percentages and patterns. It was found in the survey that all 11 participants (100%) felt that they were able to build a basic understanding of GIS. A critique from one participant, though, is as follows:

> *“I think the practical part of the worksh*op is good, but it is missing a theorical [sic] *part first that teaches you the foundations of GIS (main uses, features).”* (Informal10)

From these participants, 1 (9%) felt extremely confident that they could reproduce a Story Map after the workshop, 4 (36%) felt highly confident, 4 (36%) felt moderately confidently and 2 (18%) felt somewhat confident. When asked how motivated they were to continue to use GIS, 1 participant was extremely motivated (9%), 4 participants were highly motivated (36%), 3 participants were moderately motivated (27%) and 3 participants were somewhat motivated (27%). Two participants shared their opinions:

> *“seems really interesting but not quite sure how it could apply to my own research”* (Informal5)

> *“I’d be interested in making another map with a topic closer to my interests”* (Informal11)

Of the GIS&T BoK KAs, 10 participants (91%) felt Analytical Methods was relevant; 9 participants (82%) felt Cartography and Visualisation was relevant; 7 participants (64%) felt Data Manipulation was relevant; 6 participants (55%) felt Data Modeling and GIS&T and Society were relevant; 5 participants (45%) felt Geospatial Data was relevant; 4 participants (36%) felt Conceptual Foundations and Organizational and Institutional Aspects were relevant; 3 participants (27%) felt Design Aspects was relevant; and 2 participants (18%) felt Geocomputation was relevant (Figure 8.12).

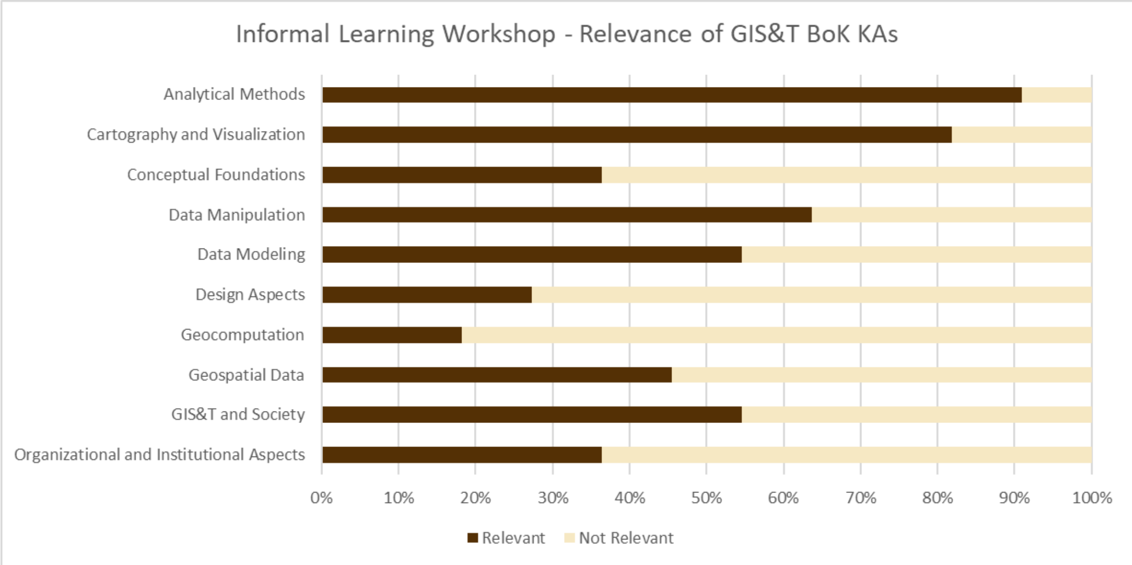


Figure 8.12 Informal workshop participants' perception of relevance of GIS&T BoK KAs from follow up survey

With regard to the perceived effectiveness of learning resources that may have been available, as illustrated in Figure 8.13, internet search was considered very effective by 2 participants (18%) and effective by 6 participants (55%); no participants considered it to be not effective and 3 participants (27%) considered it not applicable. Ask a more experienced person was considered very effective by 3 participants (27%), effective by 3 participants (27%), not effective by 1 participant (9%) and not applicable by 4 participants (36%). Follow a tutorial was considered very effective by 1 participant (9%), effective by 3 participants (27%), not effective by 1 participant (9%) and not applicable by 6 participants (55%). The software help was considered very effective by 1 participant (9%), effective by 1 participant (9%), not effective by 1 participant (9%) and not applicable by 8 participants (73%). All 11 participants (100%) felt that posting on a forum or watching a video were not applicable.

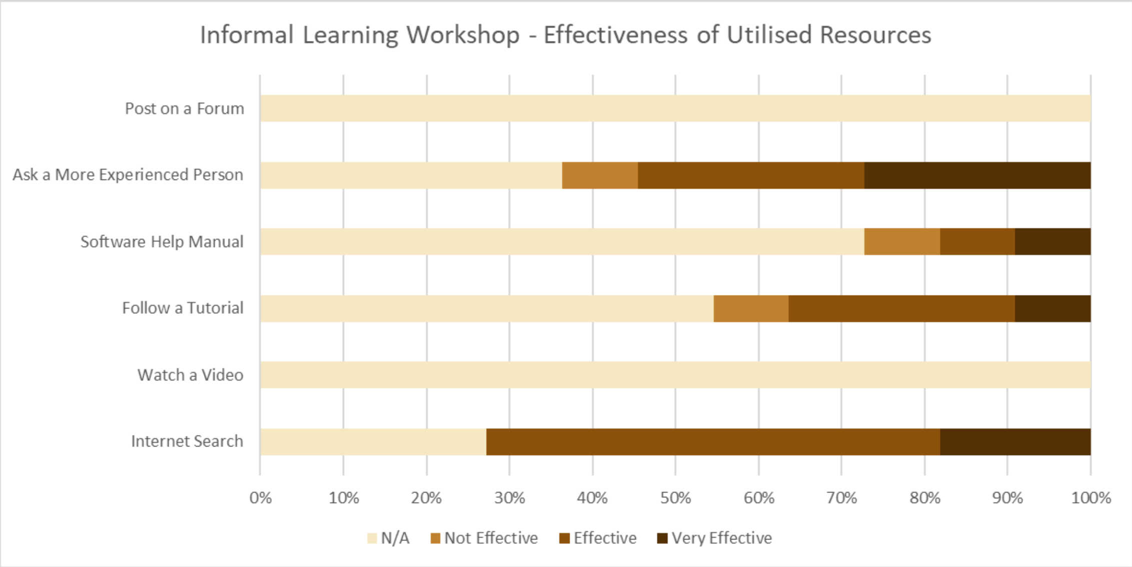


Figure 8.13 *Informal workshop participants' perception of the effectiveness of learning resources from the follow up survey*

8.5 Comparing Formal and Informal Workshops: Learning and Follow-up Activity Task Completion Times

Further work was carried out to explore the comparative details between task completion times in the formal and informal workshops. As detailed earlier (8.3.1 Screen Recordings, 8.4.1 Screen Recordings), these were recorded by reviewing participants' screen recordings and using a stopwatch to note the exact time participants completed a task. Overall time spent not on ArcGIS Online, but on websites associated with internet searches or instructional materials was also recorded using another stopwatch (as detailed in 8.1.1 Formal/Informal Learning Workshops – Study Design); this was not discounted from task completion times in both workshops and is worth bearing in mind with regard to learning activity results. To compare these between participants in the formal and informal workshops, start times were normalised to account for the possibility of tasks being completed in a different order. These results were then tabulated and graphed using box plots.

Box plots for each of the tasks for the learning and follow up activities have been created and are available in full in A.6.6 Task Completion Times – Comparing Formal and Informal Workshops. These include descriptive text about the task completion time medians and IQR. Some findings that are worth exploring in detail, though, are on the Search for and Add Layer task as well as the Add text and image to Story Map.

The box plots for learning and follow up activity for the Search for and Add Layer task can be seen in Figure 8.14.

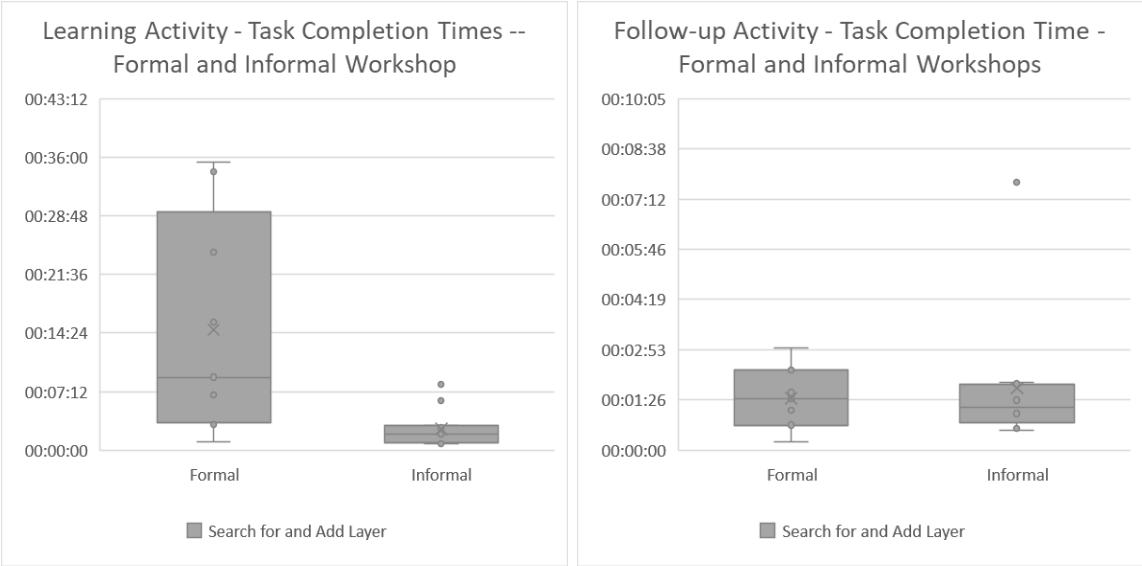


Figure 8.14 Learning Activity and Follow-up Activity – Task Completion Times – Formal and Informal Workshops: Search for and Add Layer

The completion for this task in the learning activity shows that for the formal workshop, the median completion time was 00h:08m:58s and in the informal workshop, the median completion time was 00h:01m:58s. Comparing the formal and informal workshop results, the informal workshop median was 00h:07m:00s earlier than the formal.

For the follow-up activity for this task, the median completion time for the formal workshop was 00h:01m:28s and for the informal workshop, it was 00h:01m:13s. Comparing the formal and informal workshop results, the informal workshop median was 00h:00m:15s earlier than the formal workshop.

The box plots for learning and follow up activity for the Add text and image to Story Map can be seen in Figure 8.15.

Figure 8.15 Learning Activity and Follow-up Activity – Task Completion Times – Formal and Informal Workshops: Add text and image to Story Map

The completion for this task in the learning activity shows that for the formal workshop, the median completion time was 00h:09m:51s and for the informal workshop, the median completion time was 00h:04m:31s. Comparing the formal and informal workshop results, the informal workshop median was 00h:05m:20s earlier than the formal workshop.

The completion for this task in the learning activity shows that for the formal workshop, the median completion time was 00h:01m:54s and for the informal workshop, it was 00h:01m:43s. Comparing the formal and informal workshop results, the informal workshop median was 00h:00m:11s earlier than the formal workshop.

What can be seen from both of these tasks is that participants in the formal workshop took longer to do them, particularly in the learning activity, than those in the informal workshop. Again, time spent on learning materials has been included in participants' completion times. Furthermore, those in the formal workshop did spend more time on learning materials, as they were going through the lessons in GL4U, whereas those in the informal workshop could have just figured out how to do the tasks through trial and error with functionality in the interface. However, what is worth noting is that the median completion times in the follow-up activity are almost the same for both the formal and informal workshops. This may perhaps signify that both learning approaches enabled learners to recall how to do and repeat these tasks in the GIS equally effectively.

Compiling the information from both the Learning and Follow-up Activities from both workshops, Table 8.11 summarises the completion times (medians) for all tasks (with full details, again, available in A.6.6 Task Completion Times – Comparing Formal and Informal Workshops). The completion time median that occurred earlier, in comparison between the formal and informal workshops, has been highlighted in bold and the difference between times has been included. From these results, it may be seen that, similar to the Search for and Add Layer task and the Add text and image to Story Map task, other tasks also took longer for participants in the formal workshop to complete, most of them in the learning activity; again, possibly because of the time taken to progress through the lessons in GL4U. This was the case except for the Add KML, Add Map Notes Layer and Finish Story Maps tasks. For the follow-up activity, most tasks were completed in roughly the same amount of time between the formal and informal workshops; however, it seems it took informal workshop participants longer to complete the Add SHP task and it took the formal workshop participants longer to complete the Map Notes point and info task. Overall, the formal median was earlier than the informal one in 3 of the 13 tasks (23%) for the learning activity and 6 of the 13 tasks (46%) in the follow up activity. This may mean that participants in the informal workshop were able to learn how to do GIS tasks more quickly and recall how to do them, based on memory cues created during the learning activity, than the ones in the formal workshop. Further research may wish to verify if this remains to be the case overall or if trends emerge associated with specific tasks.

Table 8.11 Comparison of Formal and Informal Workshop Task Completion Times (Medians) in Learning and Follow-up Activities

	LEARNING ACTIVITY			FOLLOW-UP ACTIVITY		
	Formal Median	Informal Median	Difference	Formal Median	Informal Median	Difference
Move Around / Zoom in/out	00h:03m:26s	00h:00m:19s	00h:03m:07s	00h:00m:07s	00h:00m:06s	00h:00m:01s
Change Basemap	00h:04m:27s	00h:01m:15s	00h:03m:12s	00h:00m:09s	00h:00m:22s	00h:00m:13s
Search for and Add Layer	00h:08m:58s	00h:01m:58s	00h:07m:00s	00h:01m:28s	00h:01m:13s	00h:00m:15s
Add SHP	00h:04m:00s	00h:02m:49s	00h:01m:11s	00h:00m:55s	00h:01m:19s	00h:00m:24s
Change Style	00h:04m:19s	00h:01m:32s	00h:02m:47s	00h:00m:26s	00h:00m:26s	00h:00m:00s
Add KML	00h:01m:59s	00h:05m:55s	00h:03m:56s	00h:01m:16s	00h:01m:24s	00h:00m:08s
Add Map Notes Layer	00h:01m:02s	00h:06m:15s	00h:05m:13s	00h:00m:57s	00h:00m:35s	00h:00m:22s
Map Notes point and info	00h:02m:44s	00h:02m:33s	00h:00m:11s	00h:01m:29s	00h:00m:47s	00h:00m:42s
Save Map	00h:05m:03s	00h:01m:50s	00h:03m:13s	00h:00m:55s	00h:00m:59s	00h:00m:04s
Share Map	00h:06m:00s	00h:00m:28s	00h:05m:32s	00h:00m:28s	00h:00m:23s	00h:00m:05s
Create Web App	00h:04m:57s	00h:03m:23s	00h:01m:34s	00h:00m:55s	00h:01m:10s	00h:00m:15s
Add text and image to Story Map	00h:09m:51s	00h:04m:31s	00h:05m:20s	00h:01m:54s	00h:01m:43s	00h:00m:11s
Finish Story Map	00h:01m:09s	00h:03m:45s	00h:02m:36s	00h:00m:16s	00h:00m:21s	00h:00m:05s

As the task completion times are considered, it may also be worth noting the amount of time participants spent on anything other than ArcGIS Online and how that may have affected the reported timings. While reviewing the screen recordings, as detailed in 8.3.1 Screen Recordings and 8.4.1 Screen Recordings and as mentioned in 8.1.1 Formal/Informal Learning Workshops – Study Design, another stopwatch was used to record overall time not spent on ArcGIS Online, but on GL4U, websites associated with internet searches or instructional materials. It is worth noting that this was not carried out at the individual task level due to questions of accuracy in recording this (explored in greater detail in 8.6.1 Measuring GIS Task Completion Times) and so only overall times have been recorded. Figure 8.16 and Figure 8.17 show the average of time spent on ArcGIS Online and otherwise from all participants in the formal and informal workshops in the Learning and Follow-up Activities respectively. These times have been summarised in Table 8.12.

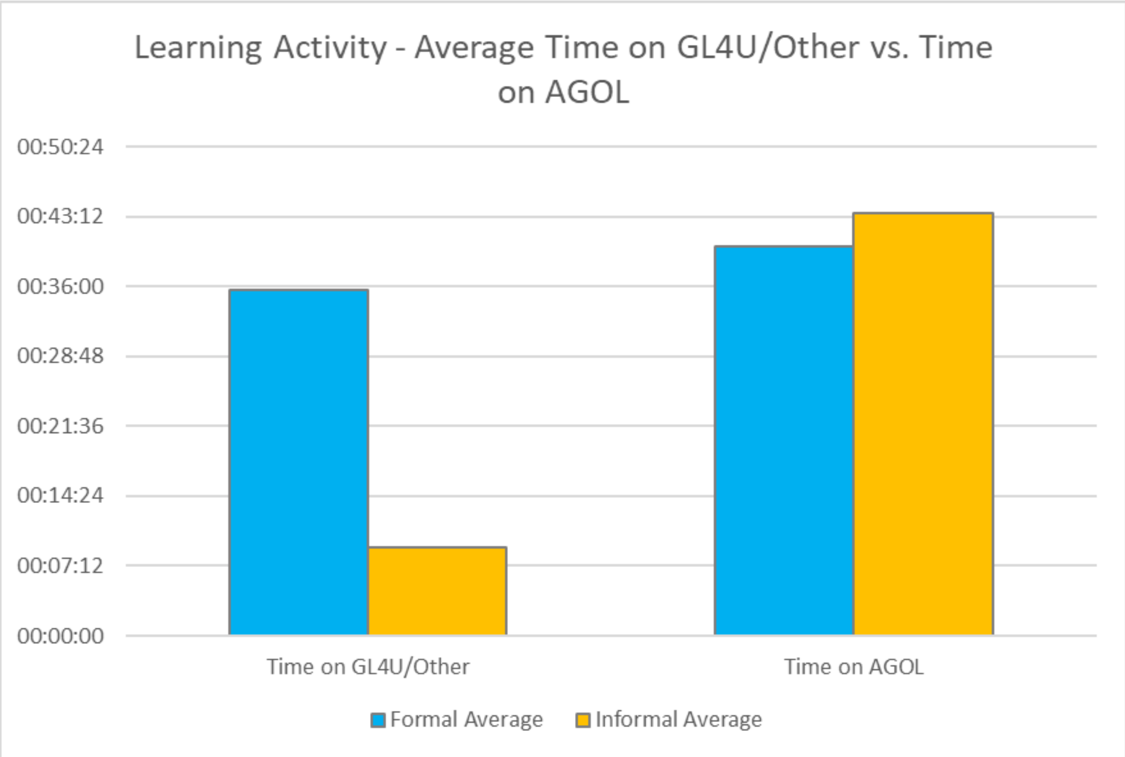


Figure 8.16 Learning Activity – Average Time on GL4U/ Other vs. Time on ArcGIS Online (AGOL)

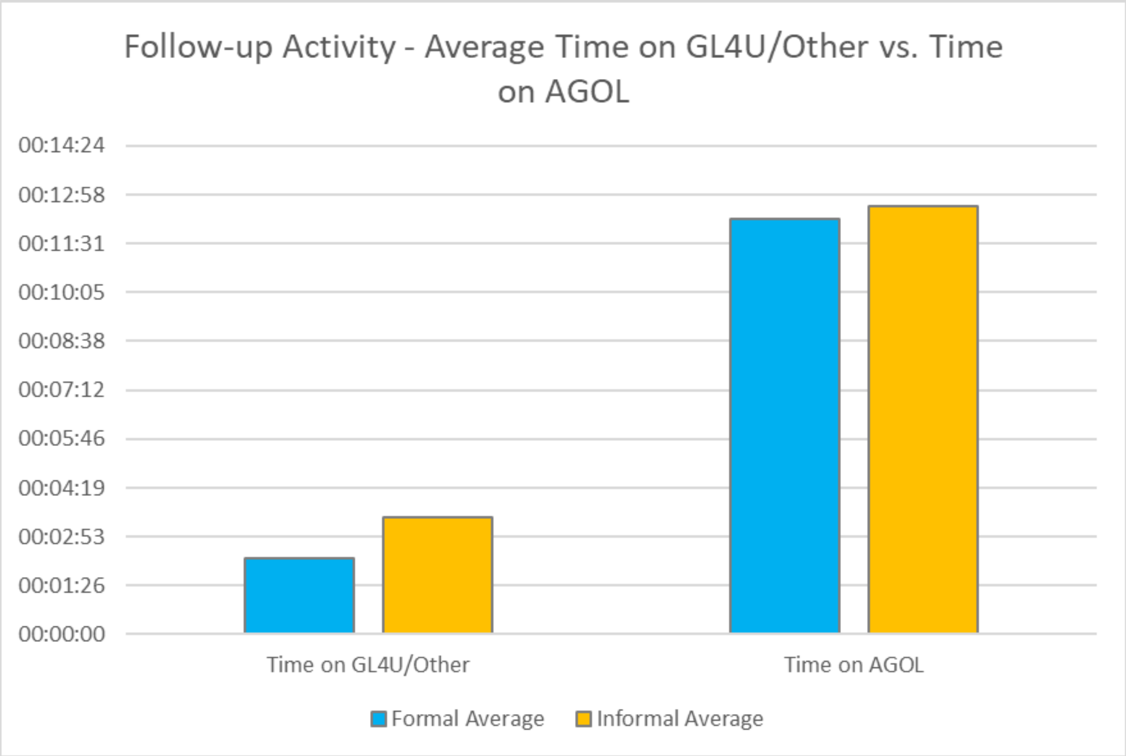


Figure 8.17 Follow-up Activity – Average Time on GL4U/Other vs. Time on ArcGIS Online (AGOL)

Table 8.12 Learning and Follow-up Activity times in Formal and Informal Workshops for time spent on GL4U/Other and ArcGIS Online (AGOL)

	LEARNING ACTIVITY		FOLLOW-UP ACTIVITY	
	Formal	Informal	Formal	Informal
Average Time on GL4U/Other	00h:35m:39s	00h:09m:09s	00h:02m:16s	00h:03m:26s
Average Time on AGOL	00h:40m:05s	00h:43m:35s	00h:12m:15s	00h:12m:38s
Total	01h:15m:44s	00h:52m:45s	00h:14m:30s	00h:16m:04s

Between the comparisons of the task completion time results for the formal and informal workshops as well as time spent on learning materials, it can be seen that the informal learners were able to complete tasks in the learning activity more quickly and they spent less time on learning materials. The formal learners, though, spent less time on learning materials for the follow up activity and were able to complete the tasks in a shorter amount of time; however, this was only by a small margin.

Bearing in mind time spent searching for information, it is worth noting the prominence of certain terms – specifically the GIS platform (ArcGIS), the item to be output from the workshop (Story Map) and a few terms associated with problematic concepts from the workshops (tabbed layout, configurable app, KML).

8.6 Discussion

The formal and informal learning workshops provided interesting insight into the learning experience of the participants and highlights emerging themes that may be relevant to interdisciplinary researchers learning GIS. The purpose of these workshops was to investigate, in a structured manner, how formal and informal learning approaches compare and contrast. This was examined in terms of learners' ability to build a basic comprehension of GIS to complete tasks, complete the identified tasks in a timely fashion, and find and understand learning materials.

After designing the workshops and recruiting participants for them, which yielded responses from 158 people across 48 different disciplines, 20 people were selected with 9 participating in the formal workshop and 11 in the informal one. In the formal workshop, average completion time of the learning activity was 01h:15m:44s and for the follow-up activity was 00h:14m:30s. Between participants, only 6 searches were made, which were on issues they had with the GIS or for more information on the technology or context of the lesson. These participants all felt that Cartography and Visualization, Analytical Methods and Data Manipulation were important GIS concepts. Following a Tutorial or Asking a More Experienced person were considered the most effective methods of gathering information; however, no one considered the Software Help Manual and or Watching a Video to be effective. In the informal workshop, average completion time of the learning activity was 00h:52m:45s and for the follow-up activity was 00h:16m:04s. Participants in this workshop made 53 searches, which highlighted difficulties understanding KML and with functionality of the GIS platform. The most important GIS concepts to these participants were Analytical Methods and Cartography and Visualization. For information gathering techniques, Internet Search and Ask a More Experienced person were considered most effective.

Comparing the formal and informal workshops, all participants were able to build a basic understanding of GIS and complete all the tasks given to them. Those in formal workshop, though, felt more confident in their ability to reproduce a Story Map and were motivated to continue to use GIS, but only marginally so in comparison to the informal workshop. Participants in the informal workshop completed almost all of the tasks in the learning activity before those in the formal workshop. This may have been because of the longer amount of time spent on learning materials, which was not discounted from task completion time. However, in the follow-up activity, even though informal workshop participants completed more tasks quicker than the formal workshop participants, this was more evenly split.

The following sections will discuss the commonalities and differences of the workshops with respect to information gathering, patterns around GIS use and concepts, their structure and implications about the learning approaches.

8.6.1 Measuring GIS Task Completion Times

As the screen recordings provided an in-depth analysis of what was completed in the GIS and how long it took, there were some noted discrepancies between the observed actions and the reported ones from the follow up survey. Completion times for the learning and follow up activity from the follow-up survey were not included in the reported results, as those from the screen recordings were used instead for greater accuracy. Completion times given by participants were often later than when they had actually completed the Story Map, as they used the time when the Story Map was checked by the researcher or volunteers, rather than when they had actually completed it. Participants also reported completing tasks in the follow-up survey that they actually had not completed in the GIS; for example, in neither the learning or follow-up activities had Formal6 changed the basemap or had Informal7 and Informal9 shared the map – yet they listed these as completed in the follow-up survey.

Time on GL4U/Other was recorded when the mouse was on the browser window or tab with GL4U/Other materials, though this may not be an entirely accurate method. For example, when participants used two windows side by side, with the GIS in one and other materials in the other, if their mouse was on the window with the GIS and it stopped moving, this may have been because they were reading materials in the other window; however, this was not logged as time on GL4U/Other, as their mouse was not in that window. Regardless, the methodology used proved to be sufficient for this research to provide an estimate for overall time spent learning GIS and doing tasks in it; however, it should be noted that some of the results could be measured or interpreted in multiple ways. For example, eye tracking equipment and associated software, though not available at the time of this experiment, may provide a more accurate recording for this information for future research.

Bearing this in mind, time on GL4U/Other was not discounted from individual task completion times, nor were time impacts on tasks with respect to glitches or errors experienced by users. For the former, given the recording method's concerns, a detailed analysis, though interesting, would not have yielded more robust results. Furthermore, it could perhaps be said that cumulative time spent doing a task, whether in the GIS, gathering information or working through an error may be considered necessary time spent to learn to complete a task. Further research may benefit by using these findings to justify the inclusion of appropriate human-computer interaction equipment and methodologies to eliminate ambiguities and to establish refined task parameters and timing review methods.

8.6.2 GIS&T BoK Knowledge Areas: Perceived Relevance to Disciplines

With regard to understanding the relevance of the Geographic Information Science & Technology Body of Knowledge (GIS&T BoK) Knowledge Areas (KAs), participants in the formal workshop may have been in a better position to determine the KAs' relevance. This may be because of their experience with GL4U and how it was structured to engage with KAs identified as relevant to interdisciplinary researchers – namely Geospatial Data, Cartography and Visualization and Analytical Methods. Continuing to affirm the relevance of Analytical Methods and Cartography and Visualization, all formal workshop participants (100%) determined those to be relevant and 6 of the 9 participants (67%) considered Geospatial Data to be relevant. However, compared to Geospatial Data, Data Modeling was also considered relevant by 6 participants (67%), Conceptual Foundations by 7 participants (78%) and Data Manipulation by all participants (100%). The others were considered less relevant, with GIS&T and Society by 5 participants (56%), Geocomputation by 4 participants (44%), Organizational and Institutional Aspects by 3 participants (56%) and Design Aspects by 2 participants (22%). This largely falls in line with findings from previous chapters, in which these KAs were lower ranked, again, in comparison to Geospatial Data, Cartography and Visualization and Analytical Methods. None of the KAs were considered irrelevant by any of the participants, so perhaps some part of all of them, based on their descriptions, was of interest to participants.

In the informal workshop, Analytical Methods and Cartography and Visualization continued to be recognised as relevant by many, with 10 of the 11 participants (91%) considering AM relevant and 9 participants (82%) thought Cartography and Visualization to be relevant. Geospatial Data, though strongly identified as relevant in previous chapters, was only considered relevant by 5 participants (45%). GIS&T and Society, Data Modeling and Data Manipulation were considered relevant by more participants, with GIS&T and Society and Data Modeling by 6 (55%) and Data Manipulation by 7 (64%). Conceptual Foundations, Organizational and Institutional Aspects, Design

Aspects and Geocomputation were considered less relevant than Geospatial Data, with Conceptual Foundations and Organization and Institutional Aspects considered relevant by 4 (36%), Design Aspects by 3 (27%) and Geocomputation by 2 (18%), which correlates with previous chapters' findings where these KAs were ranked lower than Geospatial Data, Cartography and Visualization and Analytical Methods. Again, none of the KAs were considered irrelevant by any participants, so similar to the formal workshop, the participants in this one may have also considered some part of all of the KAs descriptions to be relevant.

Perhaps the prominence of the relevance of KAs that were less relevant in previous chapters may be due to confusion or misunderstandings associated with the given descriptions. Though the elaboration box that was provided after the question on the KAs in the follow-up survey was meant to explore in detail why participants believed the KAs to be relevant, participants' responses were largely on what they may want to use GIS for (e.g. mapping disease outbreaks, election data, etc.). This highlights that the focus of interdisciplinary researchers is on achieving specific applications with GIS, avoiding concepts considered extraneous to their application of interest and going too far into the details of GIS, as mentioned by Formal4 and Formal9 in 8.3.3 Follow-up Survey. It may be questioned, though, as to whether certain details are necessary regardless, to establish foundational knowledge in order to understand data and effectively create the applications interdisciplinary researchers are interested in. Given the detail, future research may wish to identify specific KA Units or Topics from Geospatial Data, Cartography and Visualization and Analytical Methods, and perhaps others, to see how they may, or may not, be interrelated with respect to specific interdisciplinary applications to provide more detailed recommendations.

8.6.3 Behaviour and Patterns in Using ArcGIS Online

Along with monitoring the completion of GIS tasks, the screen recordings provided insight into common behaviours of participants and issues they experienced in the GIS platform, ArcGIS Online, as chosen based on the evidence presented in Table 7.3. All participants from both workshops experienced some sort of glitch or issue with the interface, which is of particular concern to GIS educators. Learning resources, on top of teaching people how to use GIS, may need to also teach them how to handle common issues in the GIS at the same time. This might be overwhelming to learners – particularly interdisciplinary researchers who may not have the foundational technological knowledge to understand what may have gone wrong and how to fix it. From the screen recordings, it was seen that participants most often got around their issues by trying different things in the interface, searching for information or, when they could not find their answer, asking for help from the researcher or workshop volunteers. This did create difficulties, though, where participants reloaded the page without saving their map and had to start over, which happened to 16 of the 20 participants (80%). It did seem that common interface issues with ArcGIS Online were around creating/editing Map Notes, where 16 of the 20 participants (80%) had difficulties, and adding the image to the Story Map description, which 14 of the 20 participants (70%) were confused by. There was also an anomaly exhibited by participants, in that 10 of the 20 participants (50%) began by first going to what may have presumably been a familiar place in the GIS (e.g. home, work, etc.), as the area they went to was not part of the tasks they were to do. Further work might wish to explore these behaviours in detail to see if they are exhibited again in similar experiments.

8.6.4 Questions within the Workshops

As part of setting the structure of the workshops, certain decisions needed to be made to ensure the comparability between them as well as modelling a real-world scenario. Participants were told in both workshops that they could ask the researcher or workshop volunteers questions; however, the researcher or volunteers would only provide guidance for ways of thinking about issues and only directly help with technical difficulties, as previously mentioned in 8.1.1 Formal/Informal Learning Workshops – Study Design. They were also asked not to work with each other, to understand how they would work through a problem on their own, rather than simply getting the answer from someone else. This may have potentially affected the perceived relevance in the follow-up survey of the information gathering technique of “ask an experienced person”; however, this was for two main reasons. Firstly, to mimic the real world IDR situation, as in an IDR setting, there would not usually be an expert or someone else on hand to discuss how to use a GIS. Though the informal workshop specifically was meant to be closer to a real-world setting, it was still conducted in a lab using set research parameters. It is difficult to ascertain whether similar results could be derived from observed GIS learning from an active IDR project; however, future research may wish to explore this. Secondly, to focus participants’ efforts on performing internet searches, to see how they constructed them, and remove any negative impacts they may have had on each other’s GIS task completion times.

8.6.5 Informal Workshop – Access to Contexts and Data

Comparing between the formal and informal workshops, for the learning activity, formal learners had their choice of four different contexts, whereas informal learners were only given the context of precarious structures in Jose Carlos Mariategui. Both were only given the context of bombs dropped on London during World War 2 for the follow-up activity. It may have been better to give the informal workshop participants the same contexts to choose from as the formal ones. However, they were purposefully not given these contexts to ensure they could not directly use the lessons and contexts in GL4U, which were also taken offline during the informal workshop. There remained the possibility that a lack of access to a variety of contexts may have had an adverse impact on the learning activity for participants, as they may have perceived the provided context as less relevant. However, 10 of the 11 participants (91%) still considered this context for the tasks to do in the GIS to have helped them with learning it.

Regardless, it was necessary to give the informal workshop participants described tasks to do in the GIS, as outlined in Table 8.1, and data and contexts for them in order to provide structure for the workshop. As mentioned in 8.1.1 Formal/Informal Learning Workshops – Study Design, this was to simulate a real-world setting where the learner may be asked to create a map using existing data as part of an IDR project. Without giving guidance on tasks to do and data to use, participants in the informal workshop might have spent quite a bit of time trying to find data or might not do the necessary tasks for comparison between the workshops, as they would not know to do them. The intent of the workshop was not to explore how participants find data, but rather, how they find and understand information on doing tasks in the GIS. In addition, if they were to attempt to find their own data, each story map created might be different and may not have all the elements being sought after as part of this study; this would make comparability of results from the informal workshop with the formal one difficult. To compare these results and extrapolate in-depth meaning from the tasks completed in the workshops, the researcher watched each of the participants' screen recordings of which the durations ranged from 1-3 hours. Given the amount of time that this took for 20 participants, a higher number may have taken significantly longer and required more resources for evaluation. Alternatively, a less detailed approach could have been taken; however, this may have missed particular nuances (e.g. glitches in the interface, browsing to familiar locations, confusion on particular topics, etc.).

8.6.6 Participant Selection

Decisions were also made for the timing and selection of participants for the workshops that may have affected the results. Participants were classified by experience with interdisciplinary research, experience with GIS and motivation to learn GIS and based on these factors, as well as discipline, were selected. This was an attempt to ensure that there was representation from a range of disciplines at the workshops and that selected participants attend them, given their interest in the subject. Random selection from all UCL staff and students could not have been carried out as this information was not made available to the researcher due to data sensitivity concerns. Selecting participants randomly from those who responded to the recruitment survey would also not have removed bias around self-selection, as these students consciously chose to respond to the survey. Regardless, random selection from the respondents could have introduced other factors of concern. Multiple participants from the same discipline may have been selected, bearing in mind the higher number of respondents to the recruitment survey from Pharmaceutical Sciences (27) and Physics (26), which made up 34% of respondents. Though 39% of respondents had interdisciplinary research experience, those interested without such experience might also have been randomly selected, which may have raised questions around their appropriateness for the study, given the focus on interdisciplinary researchers. People with more advanced experience of GIS that responded to the survey may have also been randomly selected, which may have affected overall task completion times and associated results. As a more practical reason, if randomly selected participants were not highly motivated to learn GIS, they may drop out of the workshop or not complete it, which would involve trying to find new people to participate with short notice or fewer people completing the workshops, affecting the outputs for the study. Indeed, even with selecting highly motivated participants, 5 potential participants that were selected from the recruitment survey did not respond when contacted and 2 dropped out after being selected. One did so on the same day as the workshop they were scheduled to participate in (formal workshop), which was too short notice to arrange an alternative participant, hence why the formal workshop had fewer participants than the informal one. Though the number of participants in the formal and informal workshops were different, as the total number of participants was not large enough to be considered statistically valid, it was considered that this would not significantly distort the findings of the experiment. What was of greater interest, though, was to gather as much data as possible with the available resources to derive outputs that may be of use to further research.

8.6.7 Workshop Timing and Incentivisation

As previously stated, the timing for the workshops (3 hours) was selected based on completion time of participants using GL4U from Chapter 7. Given that informal workshop participants were not receiving the same learning opportunity as those in the formal workshop, to ensure their participation and remove incentive caused bias, it was decided to incentivise both of them. The practical aspect of this was to determine the appropriate level of funding as well as to find a funder. Having a greater number of participants and extending the time of the workshops may have allowed for more robust results and a more organic exploration of tasks, possibly allowing for the inclusion of participants finding their own data and structuring their own story for the Story Map in the informal workshop. This might have given a more realistic reflection of informal learning; however, this would have required more funds for incentivisation, which may have made finding a funder more difficult, and people may have been less inclined to participate in the study, given the time commitment. Therefore, the number of participants, time and tasks for the workshops were set and limited in the way they were.

With respect to incentivisation, studies have shown monetary incentives can improve response rate and recruitment of participants for research (Bentley & Thacker, 2004; Martinson et al, 2000; Giguere et al, 2015); therefore, this was considered necessary to recruit participants for the workshops and increase the likelihood that they complete them. Assuming people would volunteer to participate without incentivisation, given the commitment of time, may have resulted in not enough people participating in the study to yield viable results. Similar studies on educational settings to better understand concepts of GIS and learning have been carried out with more participants (Lee, 2006; Lee & Bednarz, 2009; Hall et al, 2005; Mackenzie, 1997); however, all of these have been conducted by lecturers who utilised the students from their classes, who may be considered participants in situ. Therefore, the participants (the students) had already willingly committed their time to the experiment (the class) for an agreed incentive (receiving knowledge from the class). Furthermore, as these studies were part of an academic course, this allowed the researchers to review learning over its duration, rather than as part of a short experiment (or series of experiments). Comparable studies would only be achievable if participants were similarly incentivised (e.g. monetarily, which might be quite expensive) and willing to commit their time to take part in the experiment. In the context of a research experiment, without such an incentive, there may be issues in recruitment, which is not something necessarily faced when students in a class are the participants. Therefore, it must be acknowledged that to do a similar experiment outside of a classroom may be difficult, with respect to getting a similar number of participants for a duration of time without a sufficient incentive, which may be outside of the available budget for the experiment.

Bearing this in mind, further exploration of learning with the participants was not possible as incentive for them was limited and so some outstanding questions remain. It is unknown as to whether these participants further pursued use of GIS after the workshops or use of it in their courses. The participants' responses to the follow-up survey showed their level of confidence in using GIS and their motivation for continued use; those responses may have been positively skewed, given they had answered them at the end of the workshop, having just worked with the GIS. It would be of interest to find out if they still had the same level of confidence in using GIS to create another Story Map or if that had diminished. Furthermore, if they had positively responded with respect to motivation for continued use of GIS and they stopped using it, it might be worthwhile understanding why they did not. It would be recommended that future studies that are able to conduct similar experiments over time investigate these aspects with interdisciplinary researchers, as this was not possible as part of this research.

8.6.8 Analysis and Findings from Learning Approaches

From reviewing the cumulative resulting data, there are certain commonalities and differences that begin to emerge with respect to the learning approaches. In the follow-up survey, all participants from both workshops said they felt that they were able to build a basic understanding of GIS from the workshop. Though varied from 'somewhat' to 'extremely' motivated, as mentioned in 8.3.3 Follow-up Survey and 8.4.3 Follow-up Survey, all participants from both workshops reported at the time that they were motivated to continue to use GIS. The use of relevant contexts for learning activities and resources was also preferred by almost all participants (19 of the 20 participants from both workshops [95%]). Some participants' explanations for their positive perception of relevant contexts for learning are as follows:

> *"I also tend to prefer learning things in a more applied way than just learning how to use the abstract technology, as it is just more interesting."* (Formal4)
>
> *"It [the context] was more directly related to* the type of usage [of GIS] I would *make in the future."* (Formal1)
>
> *"I found the context [for the given tasks] helped because it gave an applied example."* (Informal2)

One participant from the informal workshop (Informal3) felt the given context, which was on precarious structures in Jose Carlos Mariategui, actually hindered their learning experience, as they did not feel they understood the context or what they were doing. However, they did feel that the follow-up activity context, which was on bombs dropped on London during World War 2, was better, as this was more easily relatable.

As GL4U makes use of some contexts that may be of interest to interdisciplinary researchers, the ones in the formal workshop favourably reviewed GL4U as a learning resource for its use of contexts. All participants from the formal workshop considered GL4U to be effective, ranging from 'moderately' by some (3 of the 9 participants [33%]), ‘highly’ by others (3 of the 9 participants [33%]) and ‘extremely’ effective by the rest (3 of the 9 participants [33%]); no one considered it to be ineffective.

8.7 Summary

This chapter explored the development of and results derived from data collected from two workshops that simulated a formal and informal Learning Environment Context. This complements the work that was discussed in Chapter 7, with both learning environment and learning activity contexts recognised as central to CBL (Rose, 2012). GL4U was used in the formal workshop as the CBL structured materials to compare to the learning method used in the informal workshop, where participants used informal learning approaches (internet searches, asking a more experienced person, etc.). On the whole, though it took longer for those in the formal workshop to complete tasks because of the longer amount of time spent on learning materials, they felt more motivated to use GIS and more confident that they could reproduce a Story Map again, in comparison to the informal workshop participants. Furthermore, most participants from both workshops reported that they preferred using tutorials rather than informal learning approaches.

Ultimately, these workshops, as well as the work detailed in Chapter 7, provide some practical exploration of the interplay between elements in the proposed Modified TPACK Framework for Learning GIS in Interdisciplinary Research (Figure 6.10 Modified TPACK framework for Learning GIS in Interdisciplinary Research). This framework aims to address the knowledge gap challenge of IDR through the suggested solution of providing training. This has been derived from various parts of this research, which was carried out to understand what GIS concepts were relevant to interdisciplinary researchers, which GIS platforms they were using, how they went about learning about them and if that could be improved through a CBL approach. In the following chapter, the individual pieces of work shared throughout this report will be compared and contrasted to identify overall findings that have emerged, which further research may be able to build upon to continue to improve the GIS learning experience for interdisciplinary researchers.

Chapter 9 - Discussion

This report has detailed a number of individual pieces of work that together seek to investigate a main research question and series of sub-questions. To reiterate, the main question of this research was how can learning GIS be improved for interdisciplinary researchers? To begin to answer this question, the following sub-questions needed to be explored:

1. What challenges do people face in interdisciplinary research (IDR) and how is it suggested that they solve those issues?
2. Which GIS concepts are relevant to people in IDR?
3. Which educational approaches may be relevant to learning GIS and how do they compare to one another?
4. What are some of the learning approaches people involved in IDR have used to learn GIS?
5. Can a contextually relevant mixed formal (institutionally led)/non-formal (loosely organised) learning resource improve uptake and application of GIS in IDR?

To investigate these research questions, different methods were used to gather and analyse information. Educational approaches were explored through a literature review. IDR challenges and suggested solutions as well as GIS concepts were also derived from a literature review, which were then further examined through preliminary case studies, an analysis of articles obtained through data mining Google Scholar, a survey and interviews. The survey and interviews were also used to understand how people have learned GIS in practice, along with learning diaries. A prototype learning resource was then developed (GIS Lessons for You (GL4U)), which was used to teach interdisciplinary learners through courses and workshops.

The work in previous chapters, as visualised in Figure 1.3, applied these approaches to answer the research questions. Examining them individually:

- Chapter 1: An introduction to the issues and importance of interdisciplinary researchers learning GIS was presented as well as an outline for the research of this report.
- Chapter 2: This chapter focused on establishing the foundation of the elements that were explored through a literature review on IDR, educational approaches and GIS concepts. The work of 2.1 The Current State of Interdisciplinary Research found that there are 8 commonly occurring challenges and suggested solutions to them in IDR. In 2.2 Educational Approaches, from detailing various

educational approaches, it was suggested that Context Based Learning (CBL) might be an ideal learning approach for interdisciplinary researchers. GIS curricula were reviewed in 2.4 Geographic Information Systems Education and concepts from the Geographic Information and Science (GIS&T) Body of Knowledge (BoK) Knowledge Areas (KAs) (2.4.5 Geographic Information Science and Technology Body of Knowledge) were selected to frame those to be investigated for this research.

- Chapter 3: To verify outputs from Chapter 2, preliminary work was performed with researchers from Adaptable Suburbs (3.1 Adaptable Suburbs), Extreme Citizen Science (ExCiteS) (3.2 Extreme Citizen Science (ExCiteS)) and the Development Planning Unit (DPU) (3.3 Development Planning Unit (DPU)). Work carried out with Adaptable Suburbs and the DPU highlighted that GIS concepts from the GIS&T BoK KAs of Geospatial Data, Analytical Methods and Cartography and Visualization were most commonly of interest to interdisciplinary researchers. Both of these groups also shared that informal learning methods were often used, which included internet searches, watching videos and asking a more experienced person. Looking into researchers' experiences from ExCiteS, Difficulties Collaborating with Other Disciplines, or the knowledge gap between them, was identified as the most commonly occurring challenge. It was also found that Building Relationships and Providing Training were the most often suggested and utilised solutions.
- Chapter 4: This chapter provided a high level view and further insight into which GIS concepts were relevant to interdisciplinary researchers as well as the challenges and suggested solutions that were experienced. Initial work was carried out using a bespoke process of data mining articles from Google Scholar that showcased prominent areas using GIS in IDR. This also confirmed the findings from Chapter 3 with regard to the GIS&T BoK KAs (Geospatial Data, Analytical Methods, Cartography and Visualization) and IDR challenges (Difficulties Collaborating with Other Disciplines) and solutions (Build Relationships) of interest to interdisciplinary researchers. The survey provided further verification of the most relevant GIS&T BoK KAs of interest to researchers and showed that they often used ArcGIS, QGIS and web GIS platforms to do their work. Should they need to find information on how to do particular tasks in a GIS, the survey found that internet searches, watching a video or following a tutorial were the most effective methods of informal learning.

- Chapter 5: To provide a more detailed understanding of GIS concepts, IDR challenges/suggested solutions and how people learn GIS, the work of this chapter involved interviews with those who had previously learned GIS in IDR and reviewing learning diaries collected from interdisciplinary researchers who were actively learning GIS. Again, the same GIS concepts and IDR challenges/suggested solutions from Chapter 4 were identified as the most common ones from outputs from this chapter's work. Furthermore, the same GIS packages and informal learning approaches from the survey were again mentioned. It was also found that discipline specific language was an issue that interdisciplinary researchers faced.
- Chapter 6: Based on the findings from earlier chapters and a review of existing frameworks, the modified Technological Pedagogical Content Knowledge (TPACK) framework was constructed to suggest a structure that could be used to improve the GIS learning experience for interdisciplinary researchers (Figure 6.10).
- Chapter 7: Using the framework from Chapter 6, a learning resource titled GIS Lessons for You (GL4U) was created (detailed in 7.1 Aims for GIS Lessons for You (GL4U)) to try and address the knowledge gap by providing collaborative, formally structured materials on Geospatial Data, Analytical Methods and Cartography and Visualization that used a CBL approach. GL4U was then used to explore the dual axis of CBL, as defined by Rose (2012), first by applying it in two educational settings across terms/years to investigate the relevance of Learning Activity Contexts (LACs) with interdisciplinary researchers. This work again identified the same most commonly used informal learning approaches as well as GIS&T BoK KAs from earlier chapters. It also found that learners continued to experience similar difficulties with language; however, learning GIS through a contextually relevant LAC was perceived to improve the learning experience. It was also identified that motivation for learning GIS also may be a relevant factor, which further research may wish to explore.
- Chapter 8: Two workshops were then later held to simulate formal and informal Learning Environment Contexts (LECs), which is the second axis of CBL (Rose, 2012). Those participating in the formal workshop used GL4U to learn GIS and participants in the informal workshop were given data and tasks, as shown in Table 8.1, and sought out information on their own, as necessary. Through a comparison of task completion times between workshops and a follow up survey, it was found that though participants using informal approaches were able to

complete tasks more quickly than or in roughly the same amount of time as those using GL4U, overall, the ones that used GL4U felt more confident they could do the tasks again in a GIS and were more interested to continue to use it. Regardless of the approach, taking a tutorial was the preferred learning medium, whether delivered as part of formal or informal learning.

From these pieces of work, certain patterns and trends amongst interdisciplinary researchers began to emerge around IDR challenges and suggested solutions and the perceived relevance of GIS concepts. Differences were also found, though, with respect to the learning approaches employed. Together, these provide valuable evidence to further understand the modified TPACK framework for interdisciplinary researchers. The culmination of these findings can then be reviewed to understand how they may be used to reshape the landscape of GIS education for interdisciplinary researchers as well as Geographic Information Scientists (GIScientsts).

9.1 Findings on IDR Challenges and Suggested Solutions

Again, 2.1 The Current State of Interdisciplinary Research identified 8 commonly occurring challenges and suggested solutions to them in IDR (shown in Table 9.1), which were derived from an extensive literature review.

Table 9.1 IDR Challenges and Suggested Solutions

IDR Challenges	IDR Suggested Solutions
Difficulties Related to Collaborating with Other Disciplines	Provide Training on Technical and Supplemental Skills
Personality Conflicts	Build Relationships with Members of the Group
Time Constraints	Include Senior Staff and Interested Parties
Intransigence from Current Institutional Structure	Incorporate Effective Management Practices to Construct Clear Objectives and Evaluation
Problems Being at the Interface Between Disciplines	Increase Funding Opportunities and Adapt Existing Ones for IDR
Lack of Opportunities for People	Incentivise IDR with Support and Rewards
Licencing and Ownership Ambiguities	Establish an Institutional Structure that Prioritises IDR
Lack of Local Level Management	Discourage Disciplinary “Selfishness”

Overall, the findings from both the Google Scholar Analysis (4.1 Google Scholar Analysis) and interviews (5.1 One-on-One Interviews) confirmed that the list of theoretical issues relating to IDR is, in practice, partially correct. Reflecting on earlier outputs from the groups from Chapter 3, all had mentioned the challenge of Difficulties

Related to Collaborating with Other Disciplines and some mentioning Time Constraints. Few considered Lack of Opportunities to be an Issue. Perhaps this may have been because, though some felt participating in IDR did not provide future benefits in their discipline, most researchers did experience benefits. To ascertain this, further work should more closely investigate why researchers did or did not feel IDR opened new options for them. Similarly, from the suggested solutions, Build Relationships was mentioned by all groups and Provide Training by some. Establish an Institutional Structure that Prioritises IDR was not a solution mentioned by many, possibly because it would have been difficult for researchers to enact change at the institutional level.

Looking at these in greater detail, it was found that researchers from Adaptable Suburbs (3.1 Adaptable Suburbs) and ExCiteS (3.2 Extreme Citizen Science (ExCiteS)) as well as the people interviewed (5.1 One-on-One Interviews) identified Time Constraints to be a key challenge, though the articles reviewed from the Google Scholar Analysis did not (4.1 Google Scholar Analysis). However, all of these strands of research did identify Difficulties Related to Collaborating with Other Disciplines, or the knowledge gap, to be a prominent issue. Adaptable Suburbs team members also mentioned a Lack of Local Level Management, but this may have been a specific issue associated with this project. DPU students (3.3 Development Planning Unit (DPU)) seemed to successfully handle a variety of issues based on their ability to collaborate with group members from a variety of disciplines, circumnavigate personality conflicts and to divvy up work to handle time constraints across their year-long project.

Similarly, when reviewing the suggested solutions, Provide Training was highlighted as important to the interviewees and within the reviewed articles; ExCiteS researchers did not necessarily discount it as an option, though they did express scepticism in this solution due to potential costs and/or exacerbation of Time Constraint issues. In Adaptable Suburbs, this was attempted as a solution to an issue, though it was unsuccessful. With students from the DPU, this was also attempted and allowed students to successfully utilise GIS in their projects. Regardless, the most commonly utilised solution that was corroborated by these outputs was Build Relationships.

Altogether, this highlights the importance of these challenges and the potentials for the suggested solutions and that most commonly, interdisciplinary researchers struggle to find the time to fill the knowledge gap between disciplines, so they should build relationships and, if possible, seek focussed training to do so. Future research may wish to use these challenges and suggested solutions as an initial structure, to which an expanded and updated literature review could add to or amend them. These could also be used in further studies, as they have only been used with the cases discussed in this report, to re-evaluate their prominence.

9.2 Comparing Context Based Formal/Non-Formal Learning and Informal Learning Approaches

From this review of educational approaches (2.2 Educational Approaches), using the updated version of Loo's (2014) mapping of educational theories (Figure 6.1), it could be seen that many of these were interrelated. The preliminary outcomes from the work with groups in Chapter 3 posed postulations around the appropriateness of these for interdisciplinary researchers. Previous studies had also identified PBL as a conducive approach for teaching and learning GIS (Baker, 2002; Drennon, 2005; King, 2008); however, given the time constraint issues of interdisciplinary researchers and educators alike, CBL may be a more appropriate formally structured learning approach. In practice, though, it was found from the interdisciplinary researchers from the various pieces of work (4.2 Online Survey, 5.1 One-on-One Interviews, Chapter 7 and Chapter 8) that if necessary, they would largely use informal learning approaches, which included the following commonly utilised methods:

- Internet Search
- Watch a Video
- Take a Tutorial
- Review the Software Help Documentation
- Ask a More Experienced Person
- Post on a Forum

Table 9.2 summarises the methods' perceived effectiveness across the research of this report. From what can be seen, Internet Searches were considered the most effective and then Taking a Tutorial. Interestingly, those who had received formal education in GIS (DPU and Digital Humanities Students and those in the Formal Workshop) considered Taking a Tutorial most effective, whereas those in the Informal Workshop considered Internet Searches to be most effective. This may imply that people consider the method through which they had learned GIS to be the most effective in comparison to others.

Table 9.2 Summary of Informal Learning Approaches and their Effectiveness

Informal Learning Approach	Online Survey	Interviews	DPU and Digital Humanities Students	Formal Workshop	Informal Workshop
Internet Search	Most Effective	Most Effective	Effective	Effective	Most Effective
Watch a Video	Effective	Effective	Effective	Not Effective or N/A	Not Effective or N/A
Take a Tutorial	Effective	Effective	Most Effective	Most Effective	Effective
Review the Software Help Documentation	Effective	Least Effective	Least Effective	Not Effective or N/A	Least Effective
Ask a More Experienced Person	Effective	Most Effective	Effective	Effective	Effective
Post on a Forum	Least Effective	Effective	Not Effective or N/A	Least Effective	Not Effective or N/A

To further explore this and other findings across this research, the learning methods will be discussed in greater detail in the following sections.

9.2.1 Internet Search

Internet searches were considered a highly effective method for informal learning by those who participated in this research. This was named the most effective method by respondents to the online survey, with 15 of the 45 respondents (33%) also saying that as part of the search terms they would include the GIS platform they were using as well as specialist terms (e.g. “buffer”, “cluster”, “raster”, etc.). Of the interviewees, 10 out of 11 (91%) did internet searches, with one participant also adding that it is important to include the software name. Two interviewees (Participant E, Participant J), though, noted that a large amount of time could be spent searching for information while not knowing what to do. Combining the results from the Development Planning Unit (DPU) and Digital

Humanities students, 16 of the 54 students (30%) said they would use internet searches to find information.

Bearing these findings in mind, one of the main purposes of the workshops (Chapter 8) was to explore whether participants performed internet searches and how they constructed search terms. Though participants in the formal workshop did not make many searches, some of their actions with respect to their answers on the effectiveness of this method warrant investigation. Formal6 thought "internet searches" was not applicable, though they had searched for ArcGIS Online. Formal5 thought they were 'not very effective', though they had searched for how to unzip a file. Their issue was more about saving the file, which was solved by asking the researcher or workshop volunteer (they considered "ask a more experienced person" to be 'effective'). Formal2 thought searches were 'effective' and Formal9 thought they were 'very effective', and both did search for some information; however, reviewing their screen recordings, with regard to the information they were looking for to do what they wanted in the GIS, they were able to work through it either by themselves or after asking the researcher or volunteer[10]. The searches they did had not provided them the key information, and yet they considered it to still be 'effective'/'very effective'. Both participants considered "ask a more experience person" to be 'very effective'.

In the informal workshop, Informal2 considered internet searches to be 'not applicable', which can be corroborated from the screen recordings and review of their internet search history, as they did not perform any searches. Bearing this in mind, it is worth noting that this participant was able to complete all the tasks in the GIS through trial and error with the interface and only sought help by asking 3 questions of the researcher or volunteer (they considered "ask a more experienced person" to be 'very effective'). This participant also thought a tutorial could be 'effective', though they had not taken one; this may have been based on preference, rather than something they had actually utilised during the workshop, as they considered informal learning to only be 'somewhat effective' and said 'yes' to preferring to have taken a tutorial based learning approach instead. Informal10 made 5 searches and Informal4 made 4 searches and both said internet searches were 'not applicable', so it is unclear why they may have thought that was the case. None of the participants in the informal workshop, outside of those who said internet searches were 'not applicable', thought searches were 'not effective', which is understandable as all of the remaining participants performed internet searches.

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[10] Detailed information on participants' questions from the workshops may be found in A.6.4 Additional Workshop Findings

Concerning overall effectiveness of searches, it could be observed that participants in the workshops only found searches to be more effective if they were able to articulate themselves; otherwise, they found it easier to do so by asking a more experienced person their question, which corroborates the information shared by the earlier mentioned interviewees. Furthermore, based on the answers from workshop participants as well as 33% of survey respondents and some of the interviewees, it seemed to be common practice to include key GIS terms, perhaps seen in the GIS or related documentation, and the name GIS platform itself as part of the search terms. The workshop participants, though, did not elaborate on how they identified those key GIS terms, which further work should more deeply explore. Perhaps it is through the ability to talk around an issue, describing it to a more experienced person, and that more experienced person being able to identify the key terms for learners to investigate is where these methods combined can help interdisciplinary researchers. From the search histories of the workshop participants, key terms associated with the tasks and the GIS platform used (detailed in 8.1.1 Formal/Informal Learning Workshops – Study Design) that seem to have posed difficulty to many were “KML”, “configurable app” and “tabbed layout”. “KML” is very specific to GIS, so this may require explanation in the GIS interface; “configurable app” and “tabbed layout”, though, are specific to the GIS platform used (ArcGIS Online) and are technological and vague, so clearer terms should be used for these elements.

9.2.2 Watch a Video

Next to internet searches, watching a video was considered an effective informal learning method by many. In the online survey, 40 out of 45 respondents (89%) thought watching a video was effective. From the interviewees, 8 of the 11 (73%) watched videos to learn how do tasks in a GIS, particularly because, as put by one participant (Participant A), it is possible to follow along with instructions in the video. Though it was not necessary while going through the lessons in GL4U, 20 of the 54 DPU and Digital Humanities students (37%) said they would watch a video to learn to do GIS tasks.

Given the previously identified popularity of watching a video, it was therefore surprising that in the workshops, none of the participants used this method. Perhaps it was because of simple and clear descriptions for the tasks, matched to the terms used by the interface, that participants in both workshops were able to work through them, with minimal need for further information. As this was unexpected, questions in the follow-up survey of the workshops did not probe into why this may have been the case. If possible, similar workshops should be conducted with interdisciplinary researchers and, if videos are again not watched, participants should be asked why this is the case.

9.2.3 Take a Tutorial

Taking a tutorial, a learning method that may be used to Provide Training, which was a commonly suggested IDR solution, was also reported as commonly used by interdisciplinary researchers. 39 of the 45 respondents (87%) from the online survey thought this was an effective approach. Interviewees, though, were less inclined for tutorials, as only 5 of the 11 interviewees (45%) had used those to learn how to do tasks in a GIS. One interviewee (Participant B), though commenting about short courses, said that they would only pursue this if GIS use was to be a large part of the work they were to do and that online media for learning was not preferable in comparison to face-to-face interactions. This may perhaps be applied to online tutorials, which should consider this type of learner, who has Time Constraints, specific goals with GIS and a preferred learning style. Similarly, from the DPU and Digital Humanities students, 5 of the 54 students (9%) would have taken a course to learn to do what they wanted to do in the GIS; however, 24 of the 54 students (44%) would use a tutorial if they needed to informally learn GIS, which was the most commonly selected informal method by the students.

The preference for tutorials was further explored through the outputs of the workshops. As the formal workshop participants took a tutorial, some of their answers about this information gathering technique were interesting. 6 of the 9 (67%) considered taking a tutorial 'effective' or 'very effective'. Formal8 considered it 'very effective' and elaborated as follows:

> *"From this positive experience I'm now biased towards a formal learning* approach. However, internet searches are too messy and you need to know what you're searching for and video tutorials are annoying because you feel restricted to navigating the programme exactly as seen on the screen. The screen shots in this [GL4U] just showed me what I should be seeing but allowed me to find them *in my own ways."* (Formal8)

Similar to Formal8, Formal3 also considered a tutorial 'very effective' and again highlighted issues with searches:

> *"It [GL4U] worked for me, internet searches sometimes can be misleading and finding an appropriate link might take some time."* (Formal3)

Formal4 thought a tutorial is 'effective'; however, they would have preferred an informal learning approach and offered the following critique:

> *"Overall, many tutorials online in my experience of different software/SaaS* platforms are poorly constructed, overly technical, or based on out of date software, so I tend to avoid these unless they have been specifically recommended and have a strong community that backs them and keeps them *updated."* (Formal4)

Formal5 and Formal6 considered tutorials to be 'not applicable', though they considered the formal learning approach of taking a tutorial to be 'highly effective' and 'moderately effective', respectively. Formal7 thought a tutorial, perhaps specifically GL4U, to be 'not effective'; this participant struggled with getting through and completing the learning activity and had commented that they thought GL4U was very confusing. They were, however, able to complete the follow-up activity, and still considered the formal learning approach to be 'moderately effective'.

In the informal workshop, outside of the option to take a tour to "Learn to make a map", which only 3 of the 11 participants (27%) started and all stopped following after the first few steps, none of the participants actually took a tutorial. 6 of the participants (55%) said a tutorial was 'not applicable'. However, Informal6 considered a tutorial to be 'very effective', though they did not take one; they considered the informal approach to be 'highly effective', but would have preferred to have taken a formal tutorial – even though they thought the tutorial would not be as effective as the approach they had taken. Curiously, Informal5 thought a tutorial was 'not effective' and that the informal approach was 'highly effective', but still said they would have preferred to take a tutorial and that one would have been more effective than the informal approach. Informal4, Informal8 and Informal2 thought a tutorial was 'effective', again, even though they did not take one. Informal4 thought the informal approach was 'extremely effective', and though they had said a tutorial would be 'effective' they later said they would not have preferred one over the informal approach and that it would not have been as effective. For their elaboration as to why, they provided the following quote:

> *"If the interface is good enough, we don't have to spend time learning. We ca*n use it and learn how to use it at the same time. But of course, it may exist users *with less knowledge of informatics and who feel better following a tutorial"* (Informal4)

Informal8 thought the informal approach was 'highly effective' and though they would have preferred taking a tutorial, they thought it would not be as effective as the approach they had just taken. Finally, Informal2 thought the informal approach was 'somewhat effective' and a tutorial would have been more preferable and considered more effective than the informal approach.

Some of these responses seem contradictory, though it may be due to the nuance of whether the participants' responses about effectiveness were based on their experience of utilising the information gathering technique during the workshop or simply on their perception of the technique. Indeed, there was an overall inclination towards taking a tutorial, as 5 of the 9 participants in the formal workshop (56%) and 9 of the 11 participants in the informal one (81%) expressed a preference for a tutorial over informal learning approaches. Though they were not given information on the structure of the other workshop, perhaps these responses suggest that participants would have been curious about the alternative learning approach that was used in the workshop they had not attended. Future research may wish to take two similar cohorts through both approaches and see if there is a preference for the first or second approach to better compare formal and informal learning methods.

9.2.4 Review the Software Help Documentation

Though it is written specifically to help people learn to use it, software help documentation was not a commonly utilised learning method. From the survey respondents, 33 of the 45 respondents (73%) found it effective; however, 12 respondents (27%) found it either not applicable or not very effective. Similarly, only 3 of the 11 interviewees (27%) considered help documentation to be effective. Though not necessarily specified, DPU and Digital Humanities students may have considered reading a book to be a book about the software; assuming as such, only 2 of the 54 students (4%) considered reading a book to be effective.

The trend of lack of regard for software documentation was also exhibited through the outputs of the workshops. From the formal workshop, as up to date and comprehensive information was provided about what to do in ArcGIS Online, there was little need to review the software help documentation, so all participants considered this to be 'not applicable'. From the informal workshop, Informal3, Informal5, Informal7 and Informal11 did access ArcGIS Online help documentation; however, Informal3 and Informal5 considered software help to be 'not applicable'. Informal7 and Informal11 thought the documentation was 'effective' and 'very effective', respectively. As stated by Formal3 in 9.2.3 Take a Tutorial, links can sometimes be misleading, presumably as they may not yield to the correct answer. Indeed, Informal1, Informal6 and Informal8 made searches and did access software help documentation; however, rather than for ArcGIS Online, the documentation was for ArcGIS Desktop and ArcGIS Pro. Though they had included the name "ArcGIS" in their searches, they did not know the difference between the platforms. Unsurprisingly, they were unable to find the answers to what they were looking for, though they eventually worked through the issues themselves. Consequently, Informal1 and Informal8 considered software documentation to be ‘not applicable’ and Informal6 thought it was ‘not effective’. Outside of the informal workshop participants mentioned, the others had not accessed any software help and so considered this technique to be ‘not applicable’.

When accessing the software help documentation, it is worth noting that the participants did not do so through the ArcGIS Online interface, but rather, went to Google and searched for it. This was also often the case for creating a Story Map. 1 of the 9 participants from the formal workshop (11%) and 7 of the 11 participants from the informal one (64%) searched for “Story Maps”, accessed the main Story Maps website and clicked on the “Create Story” button on that page to create their Story Map, rather than creating it via the ArcGIS Online interface they were already logged into.

In general, future research should seek to better understand why software documentation, specifically written to assist people with using the software, is not considered effective by many and how to improve that perception. As a start, bearing in mind these findings from interdisciplinary researchers learning GIS, it may be worthwhile to make the help documentation more easily searchable through the ArcGIS Online interface or to make it more easily discoverable by a search engine. It will also be necessary to relay to those searching for help that if they are going to include the GIS platform in the search terms, as many have shared that they do, they should ensure it is the specific one they are using and to be able to differentiate between the different platforms’ documentation in order to use the correct one.

9.2.5 Ask a More Experienced Person

Asking a more experienced person can be useful, as they may be able to use their knowledge to guide learners to answers and help them better articulate their questions. As such, many of this research’s participants felt this was an effective method for informally gathering information. 39 of the 45 survey respondents (87%) felt this was an effective method. This was also the preferred method of 10 of the 11 interviewees (91%). Indeed, 4 interviewees (Participant B, Participant D, Participant E, Participant F) are quoted, showing a preference for having a more experienced person available to immediately ask questions and provide solutions. The DPU and Digital Humanities students, though, did not really consider this as a preferred method for informal learning, as only 4 of the 54 students (7%) mentioned it (all of which were from the DPU).

Workshop participants, though, were split on this method’s effectiveness for learning. From the formal workshop, 5 of the 9 participants considered such a technique to be ‘effective’ or ‘very effective’ (55%), no one thought it was ‘not effective’ and 4 (44%) considered it ‘not applicable’. Formal3 and Formal7 did ask a few questions and they considered this to be ‘very effective’; Formal5 and Formal6 also asked questions and thought this was ‘effective’. Formal2, though having asked a few questions, thought asking a more experienced person was ‘not applicable’. Formal9 did not ask any questions; however, they did think doing so is a ‘very effective’ approach.

In the informal workshop, 6 of the 11 participants (55%) thought asking a more experienced person was ‘very effective’ or ‘effective’, 1 participant (9%) thought it was ‘not effective’ and 4 participants (36%) considered it ‘not applicable’. Of those who had not asked questions in the workshop, Informal3 had considered this technique to be ‘not applicable’, which is understandable; however, the responses from Informal6 (‘very effective’), Informal7 (‘not effective’) and Informal10 (‘effective’) may simply be based on their perception of this approach, rather than from experience in the workshop. Informal4, Informal5 and Informal8 did ask questions; however, they considered this technique as ‘not applicable’. Informal2 and Informal9 did ask questions and considered this to be ‘very effective’; similarly, Informal1 and Informal11 also asked questions and considered this approach ‘effective’.

Some of these results from the workshops correlate, in that most of people who did ask questions considered this to be an effective way of gathering information and those who did not considered it not applicable. The ones that may seem to be contradictory may be due to perception of effectiveness rather than evaluation of this approach’s effectiveness in the context of the workshop. Overall, it should also be noted that it is possible that the answers relating to the effectiveness of this method from the workshops may be skewed, given that the researcher asked people not to work together and said that they would only help people with technical issues. Perhaps if they were allowed to ask more questions, that would have increased people’s rating for the effectiveness of asking a more experienced person. Future work should more carefully consider these nuances and adjust questions and the structure of the workshops accordingly.

9.2.6 Post on a Forum

Though posting on a forum is an asynchronous method of gathering information, it was not considered effective by many. From the online survey, 22 of the 45 respondents (49%) considered it effective, with the majority (51%) considering it not very effective or not applicable. 5 of the 11 interviewees (45%) considered it effective, though none of them elaborated on the reasoning for their response. None of the students from the DPU or Digital Humanities mentioned this as a possible learning method. It may have been possible that as the learning that they had engaged with was real-time, face-to-face learning that at the time of the survey they may have not been considering asynchronous learning methods; however, there is no evidence to suggest that this was the case.

This option was not viable to be further explored in the workshops. None of the participants posted a question on a forum, as time was limited and if they did, they might not have received a response to their query by the end of the workshop. As such, all participants in the informal workshop considered this to be ‘not applicable’; Only 1 of the 9 participants in the formal workshop (11%) thought posting on a forum was ‘very effective’. As this participant (Formal9) had not posted on a forum during the workshop, it may be inferred that this is based on their perception or previous experience, rather than its effectiveness as utilised in the workshop. Posting on forums may be a useful for asynchronous communication, when there is more time available; however, if that is not the case, then people may try other methods of information gathering. As identified, interdisciplinary researchers often have the challenge of time constraints, so this may not be a common method used.

9.2.7 Understanding Interdisciplinary Learning

CBL was used as an approach to teach interdisciplinary researchers how to use GIS in the work undertaken in Chapter 7 and Chapter 8; however, results of its impact for IDR are limited. The CBL structured resource used, GL4U, was shown to have improved the perception of the GIS learning experience and improved confidence in and motivation for continued use of GIS. However, identifying the relevance of a context to learners needs to be better understood if CBL is to be applied again for similar research in the future. The contexts for the lessons in GL4U were created for specific groups of learners (7.2 Interdisciplinary Learning Opportunities for GL4U); without having prior knowledge of the groups, educators may struggle to construct contexts learners may find relevant to their discipline. It may be possible that even if the context does not directly relate to the learner’s discipline, they may still find it interesting and so the context may be personally relevant; however, this would largely be coincidental. To increase the likelihood of contexts being relevant to learners, they would need to be surveyed in advance, which may be tedious or not possible. An educator could instead create a broad range of contexts for lessons in the hope that learners will find one to be relevant; however, this still does not guarantee that this will be the case for all learners. Furthermore, this may result in a lot of work for the educator to create a variety of contexts, which may not make it more efficient than PBL.

With regard to informal learning, from this experiential approach that was often used by interdisciplinary researchers, internet searches, taking a tutorial and asking a more experienced person were considered the most effective methods for information gathering. However, experience alone may not be the best teacher. As stated by Halpern and Hakel (2003), what is missing from these situations is systematic and corrective feedback about the consequences of the learners' various actions. This could be through an educator helping learners to correctly identify and articulate what they want to learn, providing instruction on more effective approaches to achieving their goals and filling knowledge gaps to ensure comprehensive understanding of topics. Formal classroom instruction would further help interdisciplinary researchers, as it provides learners information and skills they will need sometime in future when an educator is not present (Halpern & Hakel, 2003). Though it is possible, as one of the informal learning methods identified, to ask questions to a more experienced person, such a person may not be available; this is often the case in IDR, and so the learner must solve issues that may arise on their own without the background understanding formal education could provide. Nevertheless, if informal learning methods are to be preferred to formal ones, it may be useful for universities and institutions to provide a central resource of experts that can share their knowledge as/when needed. Furthermore, those creating tutorials or other informal learning materials (e.g. videos) should also maintain and update these when necessary, so interdisciplinary researchers can continue to find and rely upon them. Search engine optimisation methods should also be employed by online resources to make them more discoverable to learners – possibly incorporating relevant, similar terms to adjust for articulation inaccuracies. Although there may be benefits to operationalising informal approaches and creating resources for interdisciplinary researchers, there are no guarantees for their continuity as they may originate from a third party that no longer supports them.

Though the majority of respondents to the survey (4.2 Online Survey) and participants from Chapter 7 and Chapter 8 said they were motivated to continue to use GIS, it is unknown whether they actually did or do continue to use it. Perhaps it was a tool they used for work they had to do and they simply no longer have a need for it. It could be the case, though, that at some point in time in the future, they may need to use it again, and so they will remember how to use it or look for resources to relearn what is necessary. This begs the question as to whether it is necessary for interdisciplinary researchers to learn and retain knowledge of foreign disciplines' tools and methodologies or simply relearn them when needed. Research by Rose and Wheaton (1984) and Farr (1987) on training for and relearning of complex tasks has identified the following:

- Skills tend to decay with the passage of time
- Using appropriate retraining increases the skill of performance to the same original level
- The relearning time duration is shorter than the original learning period
- The first minutes of retraining are important (the “warming up” phenomenon)
- Long intervals between retraining demand longer relearning processes

Therefore, if an interdisciplinary researcher does not frequently use the tools/methodologies learned, it may become more difficult to recall information about them as time progresses. However, they may be able to relearn the information in a shorter amount of time, depending on when they had last had training in those skills. Ginzburg and Dar-El (2000) believe learning, forgetting and relearning are part of one continuous learning process. Bjork and Bjork (1988) believe that forgetting over time is actually an essential mental function, enabling us to access more current information in preference to older, typically less-relevant information. However, multiple memory retrieval cues, where information is linked to different concepts and contexts, can help with recollection (Halpern & Hakel, 2003). Learners’ epistemologies, though, may influence this, so it is important for an educator to determine the most appropriate approach to use for students to learn and recall knowledge, which will depend on what is to be taught, what learners already know and their beliefs about the nature of learning (Halpern & Hakel, 2003). Educational experiences tailored to interdisciplinary learners, such as GL4U, may have considerable potential, but the results on motivation and confidence may be misleading. It has been said that confidence is not a reliable indicator of depth or quality of learning (Halpern & Hakel, 2003). Similarly, another study found that one-time educational activities may produce rapid learning and high learner satisfaction, but it may nonetheless result in poor retention (Bell et al, 2008). For knowledge to remain accessible, it needs to either be regularly accessed as part of one’s practice or refreshed with regular training (Bell et al, 2008). Future research on CBL and its efficacy as a learning approach to use with interdisciplinary researchers learning GIS should either focus on groups of learners that learn and continue to use it and/or those who need to regularly retrain in it. It may then be seen if the resulting perceptions of motivation and confidence from a CBL approach are well founded and perhaps if they change over time, depending on concepts covered, learning contexts used and intervals between GIS use. Understanding these changes and interventions that were made could help inform educational practices in GIScience, improving them for both GIScientists and interdisciplinary researchers.

9.3 Relevance of the GIS&T BoK Knowledge Areas

The work of previous chapters framed GIS concepts by using the GIS&T BoK KAs, which were introduced in 2.4.5 Geographic Information Science and Technology Body of Knowledge. As stated in that section, the GIS&T BoK was used as it was a contemporary GIS curriculum that comprehensively covered geospatial concepts and was considered the successor of the internationally recognised NCGIA Core Curriculum. These concepts were grouped into 10 KAs, which were as follows:

- Analytical Methods
- Conceptual Foundations
- Cartography and Visualisation
- Design Aspects
- Data Modeling
- Data Manipulation
- Geocomputation
- Geospatial Data
- GIS&T and Society
- Organizational and Institutional Aspects

Though these were divided into 73 units, 329 topics and over 1600 formal educational objectives, the KA level was used throughout this research for the sake of simplicity. The relevance of these were investigated in the preliminary case studies (3.1 Adaptable Suburbs, 3.3 Development Planning Unit (DPU)), through a review of articles (4.1 Google Scholar Analysis), an online survey (4.2 Online Survey), interviews (5.1 One-on-One Interviews), with the students from the DPU and Digital Humanities (Chapter 7) and workshop participants (Chapter 8).

Work with the preliminary case studies explored the KAs in a rudimentary way, but showed that both Adaptable Suburbs and the DPU engaged with concepts from Geospatial Data and that the DPU further engaged with those from Analytical Methods, Cartography and Visualization, Conceptual Foundations and GIS&T and Society. Review of the articles identified by the Google Scholar Analysis showed that concepts from Geospatial Data and Analytical Methods were in 10 out of 10 articles (100%), Data Modeling and Cartography and Visualization concepts were in 9 (90%), GIS&T and Society and Data Manipulation concepts were in 6 (6%), Geocomputation concepts were in 5 (50%) and Organizational and Institutional Aspects and Design Aspects concepts were in 3 (30%). From the online survey, responses continued to show the importance of concepts from Analytical Methods and Cartography and Visualization, as these were felt to be relevant to 43 of the 45 respondents (96%) and 42 respondents (93%) respectively. Data Manipulation was considered relevant by 41 respondents (91%), then Conceptual Foundations by 49 respondents (89%). Data Modeling and Geospatial Data were both considered relevant by 39 respondents (87%). Organizational and Institutional Aspects, GIS&T and Society, Geocomputation and Design Aspects concepts were considered relevant by 36 respondents (80%), 32 respondents (71%), 30 respondents (67%) and 27 respondents (60%) respectively. It is worth noting that all the KAs were considered relevant to more than half of respondents. From the card sorting activity with interviewees, they felt Cartography and Visualization was the most relevant, as 10 of the 11 interviewees ranked it as the #1-2 most relevant KA, and 1 interviewee ranked it #5. Geospatial Data was also perceived to be quite relevant, having been ranked #1-4 by 9 interviewees, and irrelevant by 2 interviewees. Analytical Methods was also considered relevant by many, ranked #1-4 by 7 interviewees, #6 by 1 interviewee and irrelevant by 3 interviewees. The other KAs, yielded mixed results from interviewees. GIS&T and Society was ranked #1-4 by 4 interviewees, #5-7 by 4 interviewees and irrelevant by 2 interviewees. Conceptual Foundations was ranked #1-4 by 6 interviewees, #5-7 by 2 interviewees and irrelevant by 3 interviewees. Design Aspects was ranked #1-4 by 6 interviewees, #7-9 by 2 interviewees and irrelevant by 3 interviewees. Data Manipulation was ranked #1-4 by 4 interviewees, #5-6 by 3 interviewees and irrelevant by 4 interviewees. Data Modeling was ranked #1-4 by 4 interviewees, #5-8 by 3 interviewees and irrelevant by 4 interviewees. Geocomputation was ranked #1-4 by 2 interviewees, #5-8 by 2 interviewees and irrelevant by 7 interviewees. Organizational and Institutional Aspects was ranked #1-4 by 2 interviewees, #5-10 by 2 interviewees and irrelevant by 7 interviewees. Geocomputation and Organizational and Institutional Aspects may therefore have topics that may be less relevant to interdisciplinary researchers. In that respect as well, Cartography and Visualization was not considered by any of the interviewees to be irrelevant, so this KA has topics of relevance to interdisciplinary researchers.

What could be seen from this work was that Analytical Methods, Cartography and Visualization and Geospatial Data consistently emerged as KAs with concepts relevant to interdisciplinary researchers. These concepts were then incorporated into the modified TPACK framework for Learning GIS in Interdisciplinary Research (Figure 6.10), which was used to structure the lessons and contexts for GL4U (design details in 7.1 Aims for GIS Lessons for You (GL4U)). Using this resource and following up with students from the DPU and Digital Humanities afterwards, Cartography and Visualization (48%) [26 out of 54 students], Geospatial Data (30%) [16 students] and Analytical Methods (13%) [7 students] were identified as relevant to the work that many students were interested in doing. Of the other KAs, Conceptual Foundations was relevant to 4 students (7%), Organizational and Institutional Aspects to 1 student (2%) and none of the other KAs were considered relevant to the students. Finally, the relevance of the KAs was explored in both the formal and informal workshops. Between both, Analytical Methods was considered relevant by 19 of the 20 participants (95%); Cartography and Visualization by 18 participants (90%); Data Manipulation by 16 participants (80%); Data Modeling by 12 participants (60%); Geospatial Data, Conceptual Foundations and GIS&T and Society by 11 participants (55%); Organizational and Institutional Aspects by 7 participants (35%); Geocomputation by 6 participants (30%) and Design Aspects by 5 participants (25%).

What has emerged from this research is that Analytical Methods and Cartography and Visualization are KAs that have topics relevant to interdisciplinary researchers. Earlier work had identified Geospatial Data as also being quite relevant; however, Geospatial Data may be less relevant than Data Manipulation and possibly Data Modeling. Future research that seeks to help interdisciplinary researchers learn GIS should not only ensure that Analytical Methods and Cartography and Visualization topics are part of learning materials, but that topics from Data Manipulation and Data Modeling are also included. However, Geospatial Data does have many foundational GIS topics (e.g. projection systems, GPS, digitizing, metadata, etc.), so these should not necessarily be overlooked, as it may be essential to understand these to engage with topics from the other KAs.

This shows that the GIS&T BoK has comprehensive coverage of topics that are relevant to interdisciplinary researchers. As such, it provides an adequate structure for concepts that may be used by these researchers, rather than creating a new GIS curriculum specifically aimed at interdisciplinary researchers. A re-evaluation of the GIS&T BoK should also be carried out, as a newer, online version of it is now available, which is updated on a quarterly basis to allow it to evolve and adapt to new technologies and techniques. This has new KAs, units and topics that may be relevant to interdisciplinary researchers, such as one on Citizen Science (Rickles et al, 2017). Other new GIS education initiatives are also being developed, which includes the CyberGIS Body of Knowledge by Shook et al. (2019). This BoK builds on the foundation of the CyberGIS Framework (6.3.2 CyberGIS Framework), specifically includes a section on interdisciplinary communication, which was written by the researcher, and also involves authors from the GIS&T BoK (Karen Kemp and David DiBiase). Both the new GIS&T BoK and the CyberGIS BoK, as well as others that may be in development, should be reviewed with respect to their suitability for interdisciplinary researchers to ensure the most appropriate framework is used that meets their needs. Such work, though, will be the responsibility of the GIScientist, as GIS curricula can be complicated and contain domain specific knowledge that the interdisciplinary researcher is unlikely to actively seek out or immediately understand. Learning objectives should also be considered with respect to these researchers, who may have different ones in comparison to GIScientists.

9.4 Evaluating the Modified TPACK Framework

The Modified TPACK Framework for Learning GIS in IDR (Figure 6.10) was constructed in Chapter 6 and is based on the TPACK framework, which was introduced in 6.1.1 Technological Pedagogical Content Knowledge (TPACK) Framework. A variety of frameworks were evaluated in this chapter, which had elements that aligned with GIS, IDR and education. From those, the TPACK framework appeared to be the most appropriate for the aims of this research, though it required some modifications. To reiterate, the TPACK framework is made up of aspects associated with Technological Knowledge (TK), Pedagogical Knowledge (PK) and Content Knowledge (CK), as well as the overlaps and nexus between them; all of these are encompassed within the institutional Context, which may be specified as the Learning Environment Context (LEC) – one of the dual axes of CBL (Rose, 2012). The findings of this research from previous chapters can be mapped to the frameworks elements as follows:

- TK: Understanding and Application of Technology, which applies to the GIS platforms used by interdisciplinary researchers. As found from online survey (4.2.3 Results) and interviews (5.1.3 Results – Interview Questions), these were predominantly ArcGIS (Desktop or Online), QGIS and other web GIS platforms.
- PK: Learning Approaches, which are relevant to interdisciplinary researchers. Though interdisciplinary researchers often used informal learning approaches, as identified in the online survey (4.2 Online Survey), interviews (5.1 One-on-One Interviews) and learning diaries (5.2 Learning Diaries), it was earlier hypothesised that CBL may be a better approach (2.2 Educational Approaches).
- CK: Subject Area Expertise, which can be mapped to the GIS&T BoK KAs (2.4.5 Geographic Information Science and Technology Body of Knowledge). Through previous research (3.1 Adaptable Suburbs, 3.3 Development Planning Unit (DPU), 4.1 Google Scholar Analysis, 4.2 Online Survey, 5.1 One-on-One Interviews), it was found that interdisciplinary researchers engaged with concepts from Analytical Methods, Cartography and Visualization and Geospatial Data.

However, even when updating the framework with these elements, it still lacked the Learning Activity Context (LAC) (Rose, 2012), the second axis of CBL, which was central to work undertaken in Chapter 7 and Chapter 8. The LAC could affect acquisition of the TK, the method learning used for the PK and delivery of the CK. However, the LEC could constrain what could be possible to explore with the LAC and all other elements of the framework, if the necessary resources were not available. Therefore, the intermediate element of LAC was added to the TPACK to encompass TK, PK and CK, but itself be encompassed by LEC, as visualised in Figure 6.10.

This framework informed development of the learning materials for GL4U, which was then used to teach the DPU and Digital Humanities students (Chapter 7) as well as with the participants in the formal workshop (Chapter 8). As mentioned earlier (9.3 Relevance of the GIS&T BoK Knowledge Areas), between the students and workshop participants, the interdisciplinary researchers considered the GIS concepts, framed by the GIS&T BoK KAs, from Analytical Methods, Cartography and Visualization and Geospatial Data to be relevant to them. Overall, the students felt that the LAC used positively affected their learning experience (37 of the 54 students [69%]) and they gave GL4U positive feedback (49 students [91%]).

In the formal workshop, using GL4U, all 9 participants (100%) felt they were able to build a basic understanding of GIS. Though all 11 informal workshop participants (100%) felt they were able to build a basic understanding of GIS without using GL4U, comparing the two workshops, formal participants felt marginally more confident in their ability to reproduce a Story Map and were more motivated to continue to use GIS. Also, as stated in 9.2.3 Take a Tutorial, between both workshops, 14 of the 20 participants (70%) preferred taking a tutorial over informal learning methods.

Reflecting on the modified TPACK framework for learning GIS in IDR (Figure 6.9), evidence suggests that relevant GIS CK for interdisciplinary researchers are topics from Analytical Methods and Cartography and Visualization, less so those from Geospatial Data and possibly also ones from Data Modeling and Data Manipulation (9.3 Relevance of the GIS&T BoK Knowledge Areas). Overall, CBL was perceived to positively impact the learning experience and, on top of improving confidence in and motivation for continued use of GIS, it was also preferred over informal learning methods. This strengthens the case for the framework not only in specifying the Context as LEC, but also the addition of LAC to recognise its importance to the learning experience for interdisciplinary researchers. The GIS used with the students and workshop participants was ArcGIS Online; this was chosen for the reasons outlined in 7.1 Aims for GIS

Lessons for You (GL4U). Earlier work also identified interdisciplinary researcher often use desktop GIS platforms (ArcGIS Desktop and QGIS [4.2 Online Survey, 5.1 One-on-One Interviews]); future research should consider using these in similarly structured teaching situations to compare and contrast to the results derived from this work.

This framework may serve as a foundation to continue to build on for the benefit of inclusive GIS education for all. However, more exploratory work should be carried out to not only understand how to improve confidence in and continued motivation for GIS use, but also how the nuances of language used within it can be improved, which has been identified as an issue. If possible, such work should also be longitudinal, to analyse the level of success of interventions and changes over time. This would help educators understand if such efforts not only affect learnability of GIS, but also knowledge retention.

9.5 Research Methodologies and Impacts on Results

With the outputs of this research described, it should be noted that pursuing alternative pathways of inquiry in earlier work may have led to different overall results. Alongside the strengths, limitations and caveats to the research methods, described in Chapter 4, there were localised choices that may have also affected outcomes.

In the Google Scholar Analysis there was a certain amount of subjectivity to the results, both on the part of Google and the researcher. Google's categorisation, as well as the assignment of journals, seems to have been determined by them rather than following a universal schema. If certain journals were incorrectly categorised, it may have changed category totals or the journal with the highest h-5 index in the category. This might have led to a different set of articles being reviewed with different results. Google's search algorithms also use machine and account level information to tailor outputs and provide potentially more relevant results to users. Therefore, running the search code on different machines may have returned alternative results on the first page, displaying articles with different citation counts, as they were not ordered by that parameter. There is also the previously recognised issue around using "GIS" as a search term and the results that were returned included ones not related to GIS (e.g. biologist). If these anomalies were to be removed, or if one of the other GIS terms were used, counts may have differed, other articles may have been reviewed and results may have been different.

The survey was also conducted in a way where the outputs were affected by the options provided. Had the survey been administered via paper or over the phone instead of online, this may have affected the population of respondents. This could also have changed if a wider range of professional networks had been engaged. If more questions could have been asked, outputs may have led to more refined understandings and different avenues of inquiry. Options for the GIS platforms and information gathering techniques that were in the survey did not encompass all possibilities; had a more comprehensive set been given, other trends or patterns may have emerged.

Similarly, outputs from the interviews were also dependent on certain factors. The researcher had some competency in conducting interviews; however, someone with more expertise in this area may have been able to avoid unnecessary avenues of inquiry that arose or better identified ones to explore for a richer set of results.

Overall, the learning diaries did not yield the level of information that was desired from them. Had the instructions on what to record been clearer and there was the ability to review the diaries at multiple intervals to help direct outputs, these may have been of a higher quality. This in turn may have led to different conclusions, redirecting subsequent research.

For engagement with the students from the DPU and Digital Humanities (Chapter 7) as well as the participants in the Formal and Informal Learning Workshops (Chapter 8), GL4U was constructed using the technical specifications as described in 7.1 Aims for GIS Lessons for You (GL4U). Had different platforms been used or usability techniques been employed, such as embedding the GIS interface into the tutorial documentation itself, this may have affected completion time and, as such, the subsequent results. The lessons of GL4U were developed using specific contexts and lesson material initially targeted at specific groups; focusing on other groups would have resulted in different materials and contexts being developed, which in turn could have led to alternative results. Though it was earlier acknowledged that interdisciplinary students may act as an adequate proxy to researchers on active IDR projects, engaging with the latter instead of the former may have yielded other outputs.

For the workshops, changes to their parameters and structure may have had an impact on the results, such as if they were longer to allow further exploration of topics, addressed different tasks to the ones selected, allowed participants to work collaboratively or if informal participants were not given any data. With regard to participants, had there been wider advertisement, no or more monetary incentivisation, other participants recruited or perhaps in a different way, there may have been changes to the workshops findings. A major piece of analytical work from this chapter, the screen recordings, was done in a way where time spent on learning materials in the workshops and the task completion times may have been considered to have been subjectively determined; a different determination method may have changed these timings and affected the overall results.

Individually, all of these elements impacted this research to some extent, however there were particular aspects of the methodology that could have been more significant for the outcomes of this study. In particular, there were not enough results to do quantitative analyses to determine if findings were statistically significant. Indeed had there been more respondents/participants for each, results may have led to different avenues of inquiry. This perhaps could have been obtained through making contributions mandatory or offering better incentives for participation. Different analytical methods could have been used (e.g. non-parametric statistics), which may have highlighted other categories or trends from the outputs. Better phrasing of questions asked of respondents/participants may have elicited better or different results. These were to fit outputs to categorisations, such as the GIS&T BoK (2.4.5 Geographic Information Science and Technology Body of Knowledge) and IDR challenges and suggested solutions (2.1 The Current State of Interdisciplinary Research); sometimes, it was not clear which category was most appropriate for an output, therefore a determination had to be made. Had another decision been made or alternate categories been used, the outputs may have been different. Follow-up with respondents/participants was limited, given that interactions were for short time periods and largely based on voluntary participation. Had it been possible to follow up with participants regularly to adjust research methodologies or learning mechanisms, it may have been possible to derive more robust outputs. Furthermore, longer time periods for follow up could have allowed for investigation into knowledge degradation and retention. Finally, it should be noted that all respondents/participants were associated with English speaking academic institutions. As such, it may be questioned if results may be equally applicable to researchers outside of those settings. Overall, choices were made with regard to the research design based on information and options that were available at the time. Future research should consider options detailed in this section, should there be a need or interest to conduct similar work.

9.6 Reshaping GIS for Users' Needs

Through this research, it has been possible to begin to understand how interdisciplinary researchers use GIS and how they may be better supported in learning it. It was found that tutorials are a preferred option for learning to bridge knowledge gaps in IDR. With regard to GIS concepts, interdisciplinary researchers are interested in using GIS to create, analyse and visualise data. This research proposed structuring GIS learning materials using CBL, while recognising the interplay of the LEC and LAC. Results are inconclusive if this is better than informal learning approaches; however, future research should further test this with a greater number of learners over a longer period of time. Findings from such work could then be applied to improve GIS educational practise that may not only benefit interdisciplinary learners, but those from within the discipline of GIScience itself. Nevertheless, novel outputs include a custom process for data mining Google Scholar for information on IDR using GIS, the creation of a learning resource that facilitates interchangeable contexts for lessons (GL4U) and a proposed and tested framework to structure learning resources for interdisciplinary researchers learning GIS.

Based on the outputs of this work, the following recommendations may be made to interdisciplinary researchers learning GIS:

- Interdisciplinary researchers will often face difficulties collaborating with other disciplines, which relates to the knowledge gap between them. Researchers should build relationships and seek opportunities for formal or informal training on foreign discipline tools/methodologies to bridge these gaps.
- Interdisciplinary researchers learning informally should search the internet for information and tutorials to help them learn GIS. Should there be any terms used that do not make sense, they should find supplemental resources to quickly build their understanding of GIS.
- If time and resources permit it, interdisciplinary researchers should undertake formal education with GIS, as this will provide feedback on performance and understanding of GIS as well as improve confidence in using the software.
- Interdisciplinary researchers should focus on learning how to create, analyse and visualise geospatial data, as these are the most commonly utilised GIS concepts in IDR.

Bearing these outcomes in mind, if GIS educators devote more efforts to creating engaging tutorials that focus on specific concepts of relevance, improving upon existing methods, they can reach and support wider audiences of learners than they may initially conceived. Though their tutorials may have been created for learners in their own discipline, those from disciplines that would not normally use GIS, such as social sciences and humanities, may wish to use their materials to learn and apply GIS in innovative ways.

As such, similar to the above recommendations, it may be suggested that GIScientists do the following:

- GIScientists working with interdisciplinary researchers should be supportive of them, helping them learn GIS and give them the time to do so.
- GIScientists should recognise informally learned knowledge on GIS, quickly assess what interdisciplinary researchers are trying to achieve with it and provide background and supplemental information as necessary.
- GIScientists may want to construct GIS learning resources that use a variety of learning activity contexts so learners from different disciplines can engage with them.

As found in 4.2 Online Survey and 5.1 One-on-One Interviews, ArcGIS, QGIS and web GIS platforms have most often been used by interdisciplinary researchers, which suggests that industry standard software packages are able to also meet these researchers' needs. Indeed, not only is there great potential for use of GIS in other disciplines, interest in doing so is growing. Reflecting on the Google Scholar Analysis (4.1 Google Scholar Analysis), Table 9.3 shows the articles that were reviewed, their cited by count from October 2013 and their cited by count from May 2018. In this, it can be seen that many continue to be cited, which shows a lasting significance in their outputs and applications.

Table 9.3 Google Scholar Analysis – Articles Reviewed with Updated Cited By Counts (May 2018)

Category	Top Cited Article from Category	Cited by Count (Oct 2013)	Cited by Count (May 2018)	Percentage Increase
Ecology	"The influence of catchment land use of stream integrity across multiple spatial scales" (Allan, Erickson & Fay, 1997)	650	1012	56%
Remote Sensing	"GIS-Based Habitat Modeling Using Logistic Multiple Regression - A Study of the Mt. Graham Red Squirrel" (Pereira & Itami, 1991)	337	441	31%
Sustainable Development	"Energy and Environmental Aspects of Using Corn Stover for Fuel Ethanol" (Sheehan et al., 2003)	392	606	55%
Geography & Cartography	"GIS-based multicriteria decision analysis: a survey of the literature" (Malczewski, 2006)	350	1152	229%
Environmental & Occupational Medicine	"Using Geographic Information Systems for Exposure Assessment in	190	340	79%

	Environmental Epidemiology Studies" (Nuckols, Ward & Jarup, 2004)			
Environmental Sciences	"Applications of GIS to the Modeling of NonPoint Source Pollutants in the Vadose Zone: A Conference Overview" (Corwin & Wagenet, 1996)	86	106	23%
Epidemiology	"Towards evidence-based, GIS-driven national spatial health information infrastructure and surveillance services in the United Kingdom" (Boulos, 2004)	103	181	76%
Urban Studies & Planning	"Impervious Surface Coverage: The Emergence of a Key Environmental Indicator" (Arnold Jr. & Gibbons, 1996)	1098	2020	84%
Geology	"The Database of Individual Seismogenic Sources (DISS), version 3: Summarizing 20 years of research on Italy's earthquake geology" (Basili et al., 2008)	176	356	102%
Engineering & Computer Science (general)	"GIS for District-Level Administration in India: Problems and Opportunities" (Walsham & Sahay, 1999)	487	735	51%

Considering this growing interest, researchers from other disciplines will continue to increasingly use and apply GIS, potentially incorrectly, and GIScientists cannot stop that from happening. Instead, if GIScience is to be properly incorporated in IDR, it will be the responsibility of the GIScientist to actively listen to, educate and adapt to the needs of researchers to push beyond the boundaries of traditional GIScience. Furthermore, this research has shown the prolific use of informal learning by interdisciplinary researchers. Interdisciplinary researchers may not have time or resources to dedicate to a comprehensive GIS course; therefore, if it is known that they want to create, analyse and visualise data, then educators could release short, basic lessons on those topics using identified informal learning methods. This would give researchers an overview of how to achieve specific outputs, while not taking up too much time, and they could then engage with further topics if they desired.

Many tutorials, though, are created using a specific GIS package. As identified from online survey (4.2.3 Results) and interviews (5.1.3 Results – Interview Questions), interdisciplinary researchers most often use ArcGIS (Desktop and Online), QGIS and web GIS platforms. It can be difficult to keep these up to date as new versions of the software are released and some processes may change. Furthermore, each platform and each version will have their own interface, specific functionalities and issues that users must become accustomed to in order to use them. As such, people may be loath to switching to different software or a new version due to lack of familiarity and the time it may take to learn how to use the new one. Users may then become forgiving of bad design to avoid learning how to use a potentially better tool.

In the case of this research, ArcGIS Online was the platform used for teaching interdisciplinary researchers, which was selected based on the evidence presented in 7.1 Aims for GIS Lessons for You (GL4U). While analysing the results derived from learners in Chapter 7 and Chapter 8, it was important to differentiate between any issues learners encountered that were related to the GIS platform used and GIS concepts. Overall, for example, with respect to GIS concepts, discipline specific terms were consistently an issue, which suggests that language should either be simplified or better explained. Review of the screen recordings from participants (Chapter 8) allowed the opportunity to record a variety of issues experienced, specific to the GIS platform; some of which were presented at the end of 8.3.1 Screen Recordings and 8.4.1 Screen Recordings and the rest are available in A.6.4 Additional Workshop Findings. This information may be of interest to software manufacturers to use to improve their products; however, what was interesting from this was that all 20 workshop participants experienced some glitch or technical issue in the GIS platform. Even though these were related to the software, regardless, it is quite common across packages that something will go wrong and it is up to the user to fix it, and how to do so may not be readily apparent. It may therefore also be useful for learners to be taught common issues that can occur across GIS platforms and how to successfully circumnavigate them. This could be as simple as suggesting to learners to save, close the program and restart it to checking their data sources for bad values that can cause most GIS software to error.

When issues were encountered, though, as seen from some of the outputs from the learning diaries (5.2 Learning Diaries) and learners in Chapter 7 and Chapter 8, people would blame themselves. This is actually quite common when using technology where there appears to be no explanation for errors (Stanton, 2007). It is, however, a matter of how people handle those issues – either by trying to solve problems themselves or by asking a more experienced person for assistance. Even though all 20 workshop participants experienced a glitch or technical issue, 5 of the 9 participants (56%) from the formal workshop and 7 of the 11 participants from the informal workshop (64%) – altogether, 12 of the 20 participants (60%) – asked the researcher or volunteer a question. This means that 8 of the 20 participants (40%) worked through the issues they experienced themselves to successfully complete the activities. As the screen recordings were reviewed quite a while after the workshops, it was not possible to further explore with participants precisely how they were able to solve these issues and what their thought processes were. Future research may wish to purposefully build in GIS issues and specifically analyse how participants overcome them, interviewing them afterwards to successfully capture that information.

Outside of confirming that all workshop participants were over the age of 18, participants' exact ages were not recorded. This may could have been useful for assessing whether participants could be classified as digital natives. Digital natives, defined by Prensky (2001) are people who were born in or after 1980, whose lives are immersed in digital technology and are experiential learners who like receiving information quickly. It has been argued by Ng (2012), though, that the term digital native should not simply be associated with age, but rather with people's digital literacy skills and the ability to:

- carry out basic computer-based operations and access resources for everyday use
- search, identify and assess information effectively for the purposes of research and content learning
- select and develop competency in the use of the most appropriate technological tools or features to complete tasks, solve problems or create products that best demonstrate new understandings and
- behave appropriately in online communities and protect oneself from harm in digitally enhanced environments.

Bearing these skills in mind, it may have been the case that many of the workshop participants were digital natives and, as such, did not need assistance with working through issues because of familiarity with, perhaps not specifically GIS, but other similar digital platforms. This might also explain why more internet searches were not made, as participants preferred to just experiment with the technology, rather than begin by reading information from resources or take a short tutorial to quickly familiarise themselves with main functionality. Indeed it has also been said that "… a high level of digital literacy can help alleviate cognitive load that is often associated with the use of technology, hence freeing the working memory of the mind to focus on the tasks at hand and the content to be learnt rather than on the technology." (Ng, 2012, p. 1077). Therefore, as digital literacy continues to improve and expand, continual improvements to GIS interfaces and functionalities may sufficiently allow users to work out how to do tasks and focus on learning the GIS concepts. This will not entirely replace the need for accessible resources for assistance with software; however, having them as easily discoverable web pages may be better than embedding them in the software, as searching the internet for information has become a commonly performed task for work and personal purposes.

In this chapter, the findings from this research have been summarised and themes that have emerged across strands of work have been explored. These intricacies have been examined to understand their impacts and any effects they may have had on the outcomes, as well as suggestions for direction for future research. In the next chapter, key findings and final recommendations will be discussed to reiterate the lessons learned from this report and how they may be used to improve the GIS learning experience for interdisciplinary researchers.

Chapter 10 – Conclusion and Further Work

The motivation for this work initially came from my interactions with interdisciplinary researchers and observations of their difficulties learning to use and apply GIS. These researchers were experts in their own discipline's tools and methodologies and though they seemed to be enthusiastic to learn GIS, this did not translate into a high level of engagement at a practical level. The Anthropologists on Adaptable Suburbs recognised the importance of metadata for geospatial information, but even after tutorials on how to do so, they did not record this information (3.1.2 Outcomes). Though many of the Development Planning Unit (DPU) students initially attended the optional GIS tutorials, for the follow-up practical, only a total of 7 students across two years attended, with only one or two people in the groups actually doing the GIS work (7.6.1 DPU). Why had the interest in GIS dissipated? Was it because it was considered difficult to learn or in the end not relevant to the work these researchers wanted to do? What had caused this and what could be done to correct this? Although follow up with learners was limited, the answer to these questions are relevant to Interdisciplinary research (IDR) projects using GIS to increase uptake of GIS and spatial analytical methods.

As a GIScientist, my belief is that it is the responsibility of those in the discipline of GIScience to support people from outside of it to understand its important concepts, methodologies and tools. Learners may indeed be able to figure out what to do in the GIS on their own, as people become more familiar with technology that has become a ubiquitous part of daily life. Regardless, they should still be offered learning resources and support, so they do not blame themselves for unfamiliar or vague terminology as well as bad design and software issues. By assisting them, researchers may have a better experience learning what they need in order to quickly and correctly use GIS for their own purposes. While the results were inconclusive as to whether a formal educational approach using CBL was overall a better one than informally learning GIS, it was still found that learners preferred taking a tutorial and in doing so, they felt more confident to apply what they learned and were motivated to continue to use GIS. However, the use of specialist terminology was seen to be a major factor in impeding such users from finding resources and training materials.

For professional organisations or others delivering GIS education, the outputs of this research should help to advise on best practices. Firstly, the educator should carefully construct learning resources and experiences, ensuring they are not done in an ill-considered way. A challenge to this, though, is that often, the educator has no knowledge of the learners' backgrounds beforehand; as such, educators should have a diverse offering of materials and activities, aimed at a variety of learning levels. Associated with this, foundational knowledge should not be assumed with interdisciplinary researchers, as that may not have been established in their home discipline. Furthermore, as it has been seen that learners often experience technical issues with GIS, they should also perhaps be taught how to overcome these alongside the GIS concepts. Educators must be able to carefully balance all of these concepts, adapting teaching tactics as necessary to keep topics relevant and learners' attention.

Educators and learning materials will need to keep up to date with the latest tools and technologies. As these evolve, it would benefit software producers to do usability testing with non-traditional users to improve their products. Many organisations associated with these create related training that is usually delivered as one-off engagements with learners. Such organisations should strive to follow up with learners to assess knowledge retention and if what was learned is still practically being applied. Once learning materials and opportunities have been created, though, it is important to publicise them so that those who would be interested know that they exist.

Circulating resources to engage with a wide audience is important as it increases the chances of reaching out to a variety of learners. However, successfully learning and applying GIS requires background understanding of geography, cartography, databases, computer technologies and technical interfaces (Traynor & Williams, 1995). Therefore, researchers from disciplines that do not already have such foundational knowledge may have difficulty learning these subjects, as well as how to do specific tasks with the GIS. Regardless, support for learning and access to GIS should be given to everyone interested in learning it. Some may only wish to conduct basic tasks with it, while others delve into more advanced topics and many may simply want to view the outputs to inform decision-making. Based on motivations and needs, those involved on projects using GIS divide spatial and non-spatial tasks between each other, as was seen in with the DPU (7.7 Investigation into Student Applications with GIS); this is largely to manage all project tasks within the timeframe given. Ultimately, though not all of the researchers may have been, or will be, involved with development work with the GIS, they will all need to be able to understand geospatial outputs. As such, these can act as a medium for communication and commonality on a project.

Going forward, the results of this research confirm that the discipline of GIScience as a whole, and in particular GIS vendors, will need to make further efforts to bridge the knowledge gap encountered by new learners. This may be achieved by providing appropriate material that makes use of vocabulary that they will understand. An example of this might be to use natural language terms such as “putting points on a map” in comparison to “digitise” or referring to a feature’s “style” rather than “symbology”. Simplifying disciplinary terminology or offering detailed explanations, assuming no prior knowledge of GIS, can lower barriers to understanding and improving GIS education. This would not only benefit those from outside of GIScience, but also those entering the discipline, allowing expedited explanation of basic concepts and focus on more complex ones. By ensuring an efficient educational experience, this should also alleviate time constraint issues, often experienced by interdisciplinary researchers.

10.1 Contributions

Throughout this research, novel approaches were employed that used unique, custom-built tools and methodologies, which are contributing to the wider field of GIScience. Surveys, interviews and learning diaries are regularly used in social research; however, outside of this work, there are no studies yet that have used the combination of these methods with learners to investigate the nexus of the areas of GIS, education and IDR. Data mining via screen scraping processes have been performed in other work, but the code and methodology for this research was entirely bespoke. The modified Technological Pedagogical Content Knowledge (TPACK) framework for learning GIS in IDR is a novel output based on findings from this work and can help guide GIS educators for structuring learning resources. Teaching materials for GIS Lessons 4 You (GL4U) were tailored for interdisciplinary researchers learning GIS, which has not been performed in other studies, and the platform may continue to be used by educators. GL4U was built using the extensibility of the WordPress platform and existing plugins; however, I created the Post by Category and Tag Widget specifically for this work. The screen recordings from the workshops in Chapter 8 allowed for a detailed review of how interdisciplinary researchers understood (or were challenged) by the GIS interface and GIS concepts. This approach has not yet been applied in other studies with such researchers learning GIS. Altogether, developed tools, methodologies and findings from this research shed light on the under-researched, yet important area of interdisciplinary GIS education.

From these, a number of findings have been derived that advance our understanding of GIS, educational approaches and IDR. These may be summarised as follows:

- The most common challenges in IDR are time constraints and the knowledge gap. The most common suggested solutions are building relationships and providing training[11].

Lack of opportunities in IDR and establishing an institutional structure that prioritises IDR were considered the least relevant of the challenges and suggested solutions, respectively. This was perhaps because of the long-term nature of both and that it may take some time before an interdisciplinary researcher would experience these. The 8 challenges and suggested solutions were derived from a literature review (2.1 The Current State of Interdisciplinary Research) and verified through the work in this report (3.2 Extreme Citizen Science (ExCiteS), 4.1 Google Scholar Analysis, 5.1.1 Introduction). Interdisciplinary researchers that are about to undertake IDR or are currently involved in such projects may use these to identify and avoid or solve problems before they arise. No further challenges or suggested solutions emerged from later work in this report, nor were any of the already identified ones refuted.

- CBL does not necessarily provide any advantages for GIS Learners in IDR, although it is important to use contexts that the learner will understand to improve the learning experience.

CBL was identified as a potentially conducive learning theory for IDR through the literature review (2.3 Learning in Interdisciplinary Research), as it related to others utilised in similar GIS/educational/IDR studies. This and other theories were included and linked as part of an extension to Loo's Theories of Learning diagram (Figure 6.1), which now offers educators a greater selection of possible methods to employ to improve learner engagement. CBL was included as part of the modified TPACK framework for learning GIS in IDR, which was used to structure GL4U. Using this resource with learners (Chapter 7, Chapter 8), though results were inconclusive about the direct impact of CBL on learning GIS, relevant contexts were perceived by participants to improve the learning experience. Other potentially advantageous educational approaches for IDR were not identified in this work, nor were the hypothesised benefits of CBL directly disproven.

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[11] Originally published, and since updated, in Rickles, P. & Ellul, C.E. (2014a). "Identifying important geographic information system concepts in interdisciplinary research: An analysis of Google Scholar." Paper presented at GIS Research UK, Glasgow, UK.

- Interdisciplinary researchers are most interested in learning how to create, analyse and visualise information in a GIS. They often use ArcGIS, QGIS and web GIS platforms for their work.

Reviewing GIS curricula (2.4 Geographic Information Systems Education), the GIS&T BoK was selected to frame GIS concepts for this work, using 10 Knowledge Areas. The work of this report identified that predominantly, topics from Geospatial Data, Analytical Methods and Cartography and Visualization were of interest to interdisciplinary researchers (3.1 Adaptable Suburbs, 3.3 Development Planning Unit (DPU), Chapter 4, 5.1 One-on-One Interviews). These were interwoven as elements into the modified TPACK framework for learning GIS in IDR and incorporated into the lessons in GL4U. Participants in Chapter 7 and Chapter 8 also expressed interest in concepts from Data Manipulation and Data Modeling, which should be explored through further work. Overall, these findings suggest that GIScientists should focus efforts on these specific GIS concepts and software packages, as they are relevant to interdisciplinary researchers. This also shows that the GIS&T BoK adequately covers concepts relevant to interdisciplinary researchers. No further topics were identified that were not already covered by the existing Knowledge Areas. However, it was highlighted that there are issues with disciplinary language in the GIS&T BoK and with GIS in general. Interdisciplinary researchers may blame themselves for misunderstanding these or with issues using GIS. GIScientists must better explain necessary terminology or use more commonly understood words to help researchers bridge the associated knowledge gap and have a positive learning experience. The updated GIS&T BoK should be mindful of vocabulary used as it updates existing Knowledge Areas and continues to expand into new topics in order to better engage interdisciplinary researchers.

- The modified TPACK framework for learning GIS in IDR can be used by both research teams and commercial and open GIS software vendors to provide appropriate learning materials to meet learners' needs.

The TPACK framework (6.1.1 Technological Pedagogical Content Knowledge (TPACK) Framework) was reviewed and compared to other frameworks and was selected to be modified for the purposes of this research. Based on identified concepts, CBL, relevant GIS&T BoK Knowledge Areas and identified GIS packages were mapped to this, along with updating the framework to specify Learning Activity Context and Learning Environment Context (Rose, 2012). This as well as associated guidelines have been created and tested in this work[12] and were used to structure GL4U. The outcomes from engagement with learners (Chapter 7, Chapter 8) provide some validation for the framework; however, results around CBL were inconclusive. The GIS concepts largely covered what interdisciplinary researchers wanted to learn, but Data Manipulation and Data Modeling might also be of interest. ArcGIS Online was the GIS package used for teaching; future work should replicate this with other ones to ensure it is robust and extensible.

- It is possible to learn how to use a GIS successfully without any formal training. However, learners prefer a formal tutorial as this gives them more confidence in and continued motivation for using GIS.

Though CBL was a suggested approach, it was found in IDR that most often, to gather information, people would informally learn through performing internet searches that would include the name of the GIS platform, taking a tutorial or asking a more experienced person. They would also include GIS terms (e.g. “buffer”, “KML”, etc.) to specify what they were inquiring about, which highlights the importance of learning necessary vocabulary. As was seen with participants in the informal workshop, though, searches made were minimal and they largely figured out how to create the Story Maps by trial and error with the GIS interface. Regardless, taking a tutorial was still the preferred learning method by both workshops. This further verifies the applicability of the suggested solution of providing training to address the knowledge gap in IDR.

- GL4U not only demonstrated a flexible approach to GIS learning, but also how a standard website framework such as WordPress – usually used for blogging – could be adapted into a tool for creating flexible, reusable learning material.

Technological advances, not only in GIS, provide new ways of thinking about and handling challenges. A variety of technologies were evaluated for the construction of GL4U (Table 7.1) as well as GIS software packages that may be used for teaching (Table 7.3). WordPress was selected for its stability and extensibility and ArcGIS Online was chosen as it could be deployed via a web browser, rather than requiring installation and configuration. Both were well received by participants in Chapter 7 and Chapter 8; results, though, may have been different if other technologies were used. It may be

[12] Published in Rickles, P., Ellul, C.E. & Haklay, M. (2017). “A suggested framework and guidelines for learning GIS in Interdisciplinary Research.” Geo:Geography and Environment, 4(2), 1-18.

necessary for future research to reassess available technologies before undertaking similar work to ensure the ones chosen are fit for purpose.

Altogether, the Google Scholar Analysis, survey, interviews, learning diaries, students taught in the DPU and Digital Humanities and the recruitment survey for the formal and informal workshops have shown that there many interdisciplinary researchers that are learning and using GIS – and this interest is growing. As previously identified, though, one of the known challenges in IDR is the difficulty related to establishing communication and contacts outside of one's disciplinary network (Augsburg & Henry, 2009). This poses an issue with publicising findings associated with IDR, such as mine, which may inspire more researchers to undertake IDR and use GIS. It is therefore important to broadcast IDR outputs using traditional academic methods such as sharing them through conference presentations, publications and via professional networks. Researchers should also utilise more modern approaches for propagating information, such as maintaining a professional website with links to their work, actively blogging and making good use of social media platforms, such as Facebook (Facebook, 2018), Twitter (Twitter, 2018), ResearchGate (ResearchGate, 2018) and LinkedIn (LinkedIn, 2018). I have been proactive using the combination of these to convey my research, which opened up new opportunities for collaboration and further dissemination of my outputs. If others were to do the same, they may see similar benefits.

10.2 Further Work

Revisiting the literature and incorporating new studies may suggest a different framing for topics. More evidence should be collected and reviewed in the way of articles from Google Scholar and similar repositories, survey responses, interviews, learning diaries and student participants. The Google Scholar analysis returned a large number of possible articles to review and only 10 were included in the outputs; analysis of further articles may have led to new insights. Similarly, if the survey had been more widely distributed or further interviews conducted, findings and the direction taken with the research may have been different. The learning diaries were not as successful as I had hoped, as recorded outputs from current learners could have provided immediate insights into the learning process. Perhaps if students were given clearer instructions or followed up with more closely, the results from these may have been more useful. Work with the students (Chapter 7) and workshop participants (Chapter 8) was limited due to research constraints, as discussed in the respective chapters; engagement with more of both over a longer period of time could have allowed for exploration of emerging themes around confidence in and motivation for continued use of GIS as well as in-depth exploration of language issues. Regular follow-up with these learners may have also facilitated investigation into whether GIS concepts were indeed learned and retained, rather than inferring that they were based on the ability to replicate associated tasks in the GIS. This work tested short-term recall of how to create maps, which might reflect the real experience of IDR, as researchers may infrequently make maps. Bearing this in mind, learnability may perhaps be more important for tools and methodologies in IDR than memorability. However, memorability is also important, given relearning concepts can take time, and this is a known constraint that affects interdisciplinary researchers. The interplay between learnability and memorability was not explored in this work, but should be in future studies.

Given the findings of my research, if I had the opportunity to continue and improve upon this work, I believe I could discover more meaningful and insightful results. I would first seek to establish a global network of interdisciplinary researchers interested in GIS. This would require quite a bit of effort initially; however, I would hope engagement would snowball and others would help me build further connections. Synonymously, I would seek user requirements to build a learning resource system for GIS educators to use with interdisciplinary researchers that would improve upon the design of GL4U, to ensure it is sustainable and scalable. I would regularly survey and interview educators using the system to obtain their views on it and if it was meeting their needs, making required adjustments to improve use and functionality. This resource would be structured using the modified TPACK framework for learning GIS in IDR to provide further validation of or amendments to the framework. This would make it more robust and extensible for use with a variety of GIS platforms and learning approaches.

I would also hope for this resource to include web and desktop GIS platforms and be used for face-to-face, online or hybrid teaching opportunities. This network of GIScientists would then use this resource to teach interdisciplinary researchers and then follow up with learners with structurally improved surveys, interviews and learning diaries, and possibly using other methods, to gather feedback on the resource. The educators should also make these information gathering mediums a required part of their courses or projects to ensure sufficient output has been gathered for not only qualitative analyses, but quantitative ones as well, for statistical verification of results. I would also investigate learners' confidence in use of GIS, motivation to continue to use it and their perception of associated language before, during and after the learning experience. This could be achieved through collaborating with behavioural psychologists and linguists by making use of their expertise to explore these concepts. This may help GIScientists understand what it is about GIS, including related terminology or other aspects associated with the learning experience that may instil self-efficacy and encourage further use with learners. As such, beneficial elements may be retained, while counterproductive ones discarded. This would allow resources and methods of delivery to be adjusted as necessary in time to benefit current and future learners.

10.3 The Future of GIS in IDR

Based on these outputs and moving forward, it is hoped that the process of learning to use GIS and apply it in IDR is improved. Perhaps through better structuring learning resources for interdisciplinary researchers, they may be able to learn GIS more quickly and easily. By ensuring that key topics are adequately covered, learners may correctly apply spatial analyses and cartographic principles. Data and learning resources should be made more accessible so that researchers can use relevant information to make the outputs they desire in GIS. As use of GIS becomes common and applied across disciplines, GIS may then move from simply being a specialist tool, largely known by GIScientists, and become a wider skill that is integrated into many disciplines.

This is entirely possible, given advances in availability and usability of GIS. Web and mobile platforms allow users to access GIS through internet-enabled devices, rather than requiring software to be installed and configured on stand-alone computers solely for the use of trained specialists. GIS interfaces have also greatly improved; as was seen in the informal workshop (8.4.2 Search Histories), participants were able to largely figure out how to use the GIS without having to search for much information on how to use it or take a tutorial. With such advances and learning resources now readily available online, formal education is no longer the only method for learning GIS. This is allowing GIS beginners to self-educate, empowering them to use and apply GIS to achieve their own objectives – and not those set out by an educator. This shift in traditional education dynamics, though different, may facilitate new opportunities in the areas of GIS, education and IDR.

Many institutional projects and organisations are taking advantage of GIS in IDR and embedding it into their work, such as the United Nations (Error! Reference source not found.). This recognises its potential for solving not only current problems, but future ones as well. Indeed, there are exciting possibilities for the future for GIS, educational practices and IDR. GPS enabled smartphones are now commonplace and new functionalities using location are being made available. It has been estimated that 2.6 billion people, over a third of the world's total population, own smartphones (Smartphones – Statistics & Facts, n.d.) and there were 5 billion requests per week to Apple Maps alone, as reported in 2015 (Elmer-Dewitt, 2015). This suggests increasing opportunities with mobile GIS, which are already being recognised by private companies, government agencies and academic research institutes (Tsou, 2004). Future unknown developments in these technologies will surely unlock new applications and possibilities for uses not yet conceived. Similarly, advancements in education are being facilitated by conducive technologies, allowing people to learn in different ways. Massive Open Online Courses (MOOCs) are disrupting traditional classroom approaches through platforms like edX (edX, 2018), Coursera (Coursera, 2018) and Udacity (Udacity, 2018) as well as those that have been launched globally by over 800 universities (Mazoue, 2014; Shah, 2018). It was estimated in 2017 that there were a total of 81 million people who have signed up for MOOCs, with 23 million signing up in 2017 and similarly 23 million in 2016 (Shah, 2018), suggesting consistent growth. Interest in IDR as well is increasing; an analysis by Van Noorden (2015) has shown that since the mid-1980s there has been a rise in the number of paper references from one discipline to work in other disciplines in both the natural and social sciences. It was also identified in this study, though, that in the short term, IDR tended to be cited less than disciplinary research; however, over 13 years, the reviewed IDR studies had gained more citations, which shows sustained relevance. Therefore, if researchers are willing to make the investment, there are long-term benefits for pursuing IDR opportunities.

Nevertheless, learning how to quickly and adeptly apply tools and methodologies in IDR from unfamiliar disciplines can be challenging. Though GIS can be difficult to use and learn, it has the potential of positively impacting analyses and enriching outputs. Similar to other tools, interdisciplinary researchers may learn GIS, apply it for a particular purpose and then forget how to use it, if they do not continue to do so and do not need to retain knowledge about it. Should they need it again in the future though, they can undertake training to relearn it, which is part of a natural process of learning, forgetting and relearning (Ginzburg & Dar-El, 2000). Bearing this in mind with respect to interdisciplinary researchers learning GIS, GIS educators and GIScientists can adapt practices to support these new learners. In doing so, they may help grow the discipline of GIScience, making it a diverse and evolving one, welcoming of all researchers, regardless of discipline.

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Appendix 1 - Google Scholar Analysis

A.1.1 Google Metrics Categories

Table A.1.0.1 Google Metrics Categories

Academic & Psychological Testing

Accounting & Taxation

Acoustics & Sound

Addiction

African Studies & History

Agronomy & Crop Science

AIDS & HIV

Algebra

Alternative & Traditional Medicine

American Literature & Studies

Analytical Chemistry

Anesthesiology

Animal Behavior & Ethology

Animal Husbandry

Anthropology

Archaeology

Architecture

Artificial Intelligence

Asian Studies & History

Astronomy & Astrophysics

Atmospheric Sciences

Audiology, Speech & Language Pathology

Automation & Control Theory

Aviation & Aerospace Engineering

Back & Spine Health

Biochemistry

Biodiversity & Conservation Biology

Bioethics

Bioinformatics & Computational Biology

Biomedical Technology

Biophysics

Biotechnology

Birds

Botany

Business, Economics & Management

Business, Economics & Management (general)

Bynecology & Obstetrics

Canadian Studies & History

Cardiology

Cell Biology

Ceramic Engineering

Chemical & Material Sciences

Chemical & Material Sciences (general)

Chemical Kinetics & Catalysis

Child & Adolescent Psychology

Chinese Studies & History

Circadian Rhythms & Sleep

Cirminology, Criminal Law & Policing

Civil Engineering

Clinical Laboratory Science

Cognitive Science

Combustion & Propulsion

Communicable Diseases

Communication

Composite Materials

Computational Linguistics

Computational Mathematics

Computer Graphics

Computer Hardware Design

Computer Networks & Wireless Communication

Computer Security & Cryptography

Computer Vision & Pattern Recognition

Computing Systems

Condensed Matter Physics & Semiconductors

Corrosion

Critical Care

Cryogenics & Refrigeration

Crystallography & Structural Chemistry

Data Mining & Analysis

Databases & Information Systems

Dentistry

Dermatology

Development Economics

Developmental Biology & Embryology

Developmental Disabilities

Diabetes

Diplomacy & International Relations

Discrete Mathematics

Dispersion Chemistry

Drama & Theater Arts

Early Childhood Education

Ecology

Economic History

Economic Policy

Economics

Education

Educational Administration

Educational Psychology & Counseling

Educational Technology

Electrochemistry

Electromagnetism

Emergency Management

Emergency Medicine

Endocrinology

Engineering & Computer Science

Engineering & Computer Science (general)

English Language & Literature

Entrepreneurship & Innovation

Environmental & Geological Engineering

Environmental & Occupational Medicine

Environmental Law & Policy

Environmental Sciences

Epidemiology

Epistemology & Scientific History

Ethics

Ethnic & Cultural Studies

European Law

European Studies

Evolutionary Biology

Evolutionary Computation

Family Studies

Feminism & Women's Studies

Film

Finance

Fluid Mechanics

Food Science & Technology

Foreign Language Learning

Forensic Science

Forests & Forestry

French Studies

Fuzzy Systems

Game Theory and Decision Science

Gastroenterology & Hepatology

Gender Studies

Genetics & Genomics

Geochemistry & Mineralogy

Geography & Cartography

Geology

Geometry

Geophysics

Gerontology & Geriatric Medicine

Health & Medical Sciences

Health & Medical Sciences (general)

Health Policy & Medical Law

Heart & Thoracic Surgery

Hematology

High Energy & Nuclear Physics

Higher Education

History

Hospice & Palliative Care

Human Computer Interaction

Human Migration

Human Resources & Organizations

Humanities, Literature & Arts

Humanities, Literature & Arts (general)

Hydrology & Water Resources

Immunology

Information Theory

Inorganic Chemistry

Insects & Arthropods

International Business

International Economics

International Law

Language & Linguistics

Latin American Studies

Law

Library & Information Science

Life Sciences & Earth Sciences

Life Sciences & Earth Sciences (general)

Lipids

Literature & Writing

Manufacturing & Machinery

Marine Sciences & Fisheries

Marketing

Matallurgy

Materials Engineering

Mathematical Analysis

Mathematical Optimization

Mathematical Physics

Mechanical Engineering

Medical Informatics

Medicinal Chemistry

Microbiology

Microelectronics & Electronic Packaging

Microscopy

Middle Eastern & Islamic Studies

Military Studies

Mining & Mineral Resources

Molecular Biology

Molecular Modeling

Multimedia

Music & Musicology

Mycology

Nanotechnology

Natural Medicines & Medicinal Plans

Neurology

Neurosurgery

Nonlinear Science

Nuclear Medicine, Radiotherapy & Molecular Imaging

Nursing

Nutritional Science

Obesity

Ocean & Marine Engineering

Oceanography

Oil, Petroleum & Natural Gas

Oncology

Operations Research

Ophthalmology & Optometry

Optics & Photonics

Oral & Maxillofacial Surgery

Oranic Chemistry

Orthopedic Medicine & Surgery

Otolaryngology

Pain & Pain Management

Paleontology

Pathology

Pediatric Medicine

Pest Control & Pesticides

Pharmacology & Pharmacy

Philosophy

Physical Education & Sports Medicine

Physics & Mathematics

Physics & Mathematics (general)

Physiology

Plan Pathology

Plasma & Fusion

Plastic & reconstructive Surgery

Political Science

Polymers & Plastics

Power Engineering

Pregnancy & Childbirth

Primary Health Care

Probability & Statistics with Applications

Proteomics, Peptides & Aminoacids

Psychiatry

Psychology

Public Heatlh

Public Policy & Administration

Pulmonology

Pure & Applied Mathematics

Quality & Reliability

Quantum Mechanics

Radar, Positioning & Navigation

Radiology & Medical Imaging

Real-time & Embedded Systems

Rehabilitation Therapy

Religion

Remote Sensing

Reproductive Health

Rheumatology

Robotics

Science & Engineering Education

Sex & Sexuality

Signal Processing

Social Psychology

Social Sciences

Social Sciences (general)

Social Work

Sociology

Software Systems

Soil Sciences

Special Education

Spectroscopy & Molecular Physics

Strategic Management

Structural Engineering

Surgery

Sustainable Development

Sustainable Energy

Teaching & Teacher Education

Technology Law

Textile Engineering

Theoretical Computer Science

Thermal Sciences

Tourism & Hospitality

Toxicology

Transplantation

Transportation

Tropical Medicine & Parasitology

Urban Studies & Planning

Urology & Nephrology

Vascular Medicine

Veterinary Medicine

Virology

Visual Arts

Water Supply & Treatment

Wood Science & Technology

Zoology

A.1.2 Google Scholar Data Mining Code

A.1.2.1 google_scholar_miner_populate_journals.php

(Please see /Google_Scholar_Analysis/google_scholar_miner_populate_journals.php)

A.1.2.2 google_scholar_miner_generate_links.php

(Please see /Google_Scholar_Analysis/google_scholar_miner_generate_links.php)

A.1.2.3 google_scholar_miner_populate_articles.php

(Please see /Google_Scholar_Analysis/google_scholar_miner_populate_articles.php)

A.1.3 SQL Export and Key Tables

(Please see /Google_Scholar_Analysis/mining_v1_171013.sql and /Google_Scholar_Analysis/Google_Scholar_Analysis_Results.xlsx)

A.1.4 Reviewed Articles

(Please see PDFs in /Google_Scholar_Analysis/Annotated_Articles)

Appendix 2 - Online Survey

A.2.1 Survey Questions

1. Please select any/all GIS platforms used to create, analyse and present data in your interdisciplinary research project(s)
    a. Respondents were also asked to state whether for each platform they had No Experience, Some Experience, Moderate Experience or (Almost) Daily Experience; Platforms included ArcGIS, Google Earth, Google Maps, QGIS, MapInfo, Manifold and an "Other" field, in which respondents could input a GIS not listed.
2. If you could, based on your experiences, please rate the relevance of the given statements to the work you've done with GIS as part of the interdisciplinary research projects you were involved in.
    a. Respondents were asked if each statement was Not Relevant, Somewhat Relevant, Relevant, Very Relevant or Extremely Relevant; statements mapped to the GIS&T BoK KAs and were as follows:
        i. I have queried and analysed geospatial data in a GIS [Analytical Methods]
        ii. I have designed and created maps in a GIS [Cartography and Visualisation]
        iii. I have questioned the spatial relationships or philosophical perspectives of GIS data [Conceptual Foundations]
        iv. I have used GIS to prepare maps at different scales or convert map data from one format to another [Data Manipulation]
        v. I have structured and managed data in a GIS database [Data Modeling]
        vi. I have planned the system design and deployment of a GIS [Design Aspects]
        vii. I have created algorithms or modelling processes which take into account uncertainty inside a GIS [Geocomputation]
        viii. I have created new data inside of a GIS and/or used satellite imagery inside of a GIS [Geospatial Data]
        ix. I have had to be concerned about the legal aspects or ethics of the data in a GIS [GIS&T and Society]
        x. I have formatted GIS data in a way that improves its usability by others [Organizational and Institutional Aspects]

3. Please rate the effectiveness of any/all methods used for obtaining information on how to do tasks with GIS platforms you may have used when you did not know how to do them.
    a. Respondents were asked to state whether each method was Not Very Effective, Effective, Very Effective, or N/A; methods included Internet Search, Watch a Video, Follow a Tutorial, Software Help Manual, Ask More Experienced Person, Post on a Forum and an "Other" field, in which respondents could input a method not listed.
4. When searching for information in these sources, what are some example search terms you would use to try and find resources to possibly answer your questions? (e.g. trying to measure the distance between a city and the boundary of a country in QGIS, one could search using terms "QGIS find distance point boundary line") (Open Text)
5. Please state what you consider to be your home discipline. (Open Text)
6. Please briefly describe the research question(s) of the interdisciplinary research project(s) you were involved in that GIS was to be used to, at least partially, answer. (Open Text)
7. Based on your experiences with it in the context of interdisciplinary research projects, would you consider using GIS on future projects and what are your reasons for that decision? (Open Text)
8. Is there anything else about your experiences that you would like to share that you feel would be relevant to the topics covered in this survey? (Open Text)
9. Would it be alright for me to contact you, should I have any follow up questions or to possibly participate in a more in-depth, face to face interview? If so, please provide me your contact details below. (Open Text)

A.2.2 Survey Advertising Flyer

Figure A.2.1 Survey Advertising Flyer

A.2.3 Survey Response Data

(Please see /Online_Survey/Online_Survey_Responses.xlsx)

Appendix 3 - One-on-One Interviews

A.3.1 Interview Questions

1. Could you tell me about the research questions of your first interdisciplinary research project that a GIS was to be employed for as part of the analyses?
    a. Could you tell me about any/all GISs that you have used as part of your project?
    b. What was your level of involvement in these GIS analyses? This could be anything from simply looking at the outputs to make decisions to in-depth use of GIS tools to directly process and work with the raw data.
        i. How experienced with a GIS were you before this project?
            1. How did you feel about the proposed use of GIS given your level of experience?
            2. How motivated were you to use GIS for this project?
        ii. Given how you were to use GIS, what tasks did you need to learn to do in the GIS to complete the analyses that you were involved in?
            1. When you did not know how to do a task, how did you proceed to improve your knowledge on that task?
                a. <if Google search was used as a resource> What kind of search terms would you use to search for more information on how to do something in a GIS, when you may not have known about the technical term for it? (e.g. “creating points” instead of “digitisation”)
                b. How effective do you feel the methods you’ve just described were to enable you to gain the knowledge you needed?
                c. At the beginning of the project, how would you have considered the option of a short course, if it was offered, either face-to-face or online, to learn GIS and what would be your reasons for considering it or not?
                d. Reflecting on the end of the project, knowing what you know now, how would that have changed how you would’ve considered the possibility of taking a

short course, either face-to-face or online, to learn GIS and what would be your reasons for considering it or not?

i. <if they wouldn’t consider it> What would have made you possibly consider it then?

ii. If you did decide to take one, which do you feel would be more effective for you: a face-to-face course or an online one and what would be your reasons for picking one over the other?

2. So now that the project is over, what were your positive and/or negative experiences with GIS?
    a. What did you hope to get out of using a GIS?
        i. How effectively were you able to achieve those aims?
    b. How enthusiastic or motivated are you to use GIS in another project?
    c. Could you describe how confident you would feel using a GIS again to do similar tasks that you described earlier if you were asked to do them again now?

A.3.2 Interview Recordings and Outputs

(Please see participant folders in /One-on-One_Interviews)

A.3.3 Interview Notes

Participant A

Home Discipline: Anthropology

GIS Used: MapInfo, QGIS, ArcGIS, Community Maps, GPSies

Search Options Used: Ask for Help (most effective), Google, Forums, YouTube

- "Online tutorials can be a bit like pulling teeth at times."
- "I used YouTube a lot, actually. Because Web forums would often have long drawn out threads, where the answer would be kind of embedded in some sort of conversation that happened a couple of years ago, it might be an old version of arc. Whereas, I'm constantly amazed by the amount of people that film themselves doing very banal things and then put it on YouTube. I'm eternally grateful for it, as well, but also I kind of like this process of 'you click here', you can see where the arrow is going on the screen, you can see what that person is

doing, you can see the outputs of that, and they're talking you through it. You can almost, if you've got a split screen, you can just copy what they're doing. Almost robotic like..."

- "I found that a lot of the time using ArcGIS, using Arc Forums, there was an implicit, assumed knowledge that you would know that you have to go to file to find the drop down menu in which this thing you were looking for would be implanted. and battling through those, sort of, levels of where is this and where is that and how to you get to tools and how do you get to this part and how do you change from cursor to sticky hand dragging the map around when it doesn't do that in google maps and this does it in this way and this program does it in that way. That's a lot of frustrating learning time; when you have in your head a task to do, you know what you want the visualization to look like, and you know, for example, online tools could do this relatively quickly, but you need particular outputs and pdf formats and all that sort of stuff, so you have to use the arc program. So the frustration came with a sort of not knowing, not being familiar with the tools, I suppose. That only comes through practice."
- "Some tutorials for sort of advanced tasks will assume that you've done the other tutorials. And this is the problem with task based learning, in terms of 'I have a job to do and I need to learn how to do it', compared to something like doing a course, where you sort of learn stage 1, stage 2, stage 3, but then you're only going to invest in doing a course if you're going to be regularly using a GIS... as a core part of what you do. Whereas, I was using it to get through particular tasks, I wasn't the GIS person on that project, I'm not expected to be the GIS person on the project, and I probably won't use GIS regularly in my research. I'm an Anthropologist, I step away from computers and much as possible."

Interested in a Short Course: Yes

- "As long as it was a short course - 2 or 3 weeks."
- "Also, my home department have absolutely no interactions with GIS... it's not part of anything that they teach. So essentially, you're stepping away from main body of teaching, in terms of the skills you learn as an anthropology PhD student."
- "I have to get examined by anthropologists, I have to become an anthropology PhD student, I have to become an anthropology researcher. There ain't no point to learning GIS unless it directly effects the outputs of my research."

- “The problem is that, in my home department... have no recognition of this need. And to communicate the recognition of this need is very difficult... They will not understand what GIS is, in terms of the depth of skill needed to produce a simple visualisation. So in that sense, you're doing a lot of work for no recognition."

Face-to-face or Online (and why): Face-to-face

- "MapInfo is rubbish; it's counter-intuitive, it's not developed as much, it doesn't have the ability to do the things that Arc does, there not the depth of internet based forums. Arc is the standard - there's more people talking about how solve problems in arc than anything else. So you want the most help available to you so you want to use the most popular tool."
- ArcGIS crashing due to lack of adequate system spec

GIS&T KAs

1. Cartography and Visualization
2. Geospatial Data
3. Design Aspects
4. Analytical Methods
5. Data Modeling
6. GIS & Technology and Society

Irrelevant: Geocomputation, Data Manipulation, Organizational and Institutional Aspects, and Conceptual Foundations

- *Wording too general, though understood there are specific meanings in GISc that the interviewee was not aware of, and hence disempowering/frustrating
- "If I'm honest though, when I look at all of these things, I'm just like 'ugh... what?' Very vague words are used and I'm like 'well what does that mean?'"
- "What are the context of the words?... I find there's a lot of this in GIS language, there's a lot of bullshit, a lot of 'I can't be bothered to tell you what this language means'. It's an industry language, and when you mix that with academic language, you have the worst of both worlds."

IDR Challenges

1. Personality Conflicts

2. Time Constraints
3. Problems Being at the Interface Between Disciplines
4. Lack of Local Level Management
5. Difficulties Related to Collaborating with other Disciplines
6. Licencing and Ownership Ambiguities
7. Intransigence from Current Institutional Structures

Irrelevant: Lack of Opportunities for People

- All challenges framed by Personality Conflicts
- "I think there were some people who pushed their agendas more [than others]."
- "I don't think that's relevant... it's [interdisciplinary] all just a big buzzword, isn't it. Funding love it. They lick your face for it."

- "Personality conflicts - it's the precursor to everything. If you have a problem anywhere else on this scale... you can get over all of these things through channels of communication. Channels of communication close down when you have personality conflicts. When people take interdisciplinary work and the problems and differences between them as personal affronts to the progress of their research which happen to that project. It's not a personal affront to the progress of your research, it's a vital and viable part of the conversation to progress good interdisciplinary research. It's absolutely vital, then, that the people are able to communicate to each other to exercise those conversations. To pull it out, to put it on the table, work through it, and to also understand that that conversation, in itself, is productive of which many academic papers could probably be produced that are useful and people would want to read. But rather than do that, people will say 'you're being a block in the road here; you're being pernickety; you're not understanding what we need to do, you're stopping the progress here; that doesn't matter, it's theory, blah, blah, blah.'... This dismissiveness, this arrogance, will stop all the other things progressing, will stop good research."

IDR Solutions

1. Build Relationships with Members of the Group
2. Establish an Institutional Structure that Prioritises Interdisciplinary Research

3. Discourage "Disciplinary Selfishness"
4. Provide Training on Technical and Supplemental Skills
5. Increase Funding and Adapt Existing Ones for Interdisciplinary Research

Irrelevant: Incentivise Interdisciplinary Research with Support and Rewards, Include Senior Staff and Interested Parties, Incorporate Effective Management Practices to Construct Clear Objectives and Evaluation

Utilised: Incorporate Effective Management Practices to Construct Clear Objectives and Evaluation

- Suggested change: Establish an Institutional Structure that RECOGNISES (not prioritises) Interdisciplinary Research
- Incorporate Effective Management Practices to Construct Clear Objectives and Evaluation only solution utilised on the project, but may have been more of a hindrance instead of solution, as in constraint possible directions research could go.
- "A lot more listening and understanding, in terms of interdisciplinary projects. A lot more time carved out to listen to what other disciplines do..."
- "In interdisciplinary research there is no time in that traditional framework to have the conversation about what different disciplines are, what new sorts of analytical approaches might be used, methodological approaches might be used, it is almost an entire new stage into this sort of research, really, that isn't recognised by the academy yet - and needs to be, I think."

Participant B

Home Discipline: Evolutionary Biology

GIS Used: Open Street Map, bespoke web GIS, Manifold

- Doesn't consider web map to be GIS [not the only one to think that]
- Self-deprecating of skills
- "...[my skills are] mediocre because I can't build complex scripts."

Search Options Used: Ask for Help, Google

Interested in a Short Course: Probably Not

- “I probably wouldn't have done a course, unless it was taking up a large proportion of what I needed to do, I just wouldn't have seen the relevance of doing a course. If it was taking up 50% of my workload then yes, of course it would be beneficial. But to do a course when actually it's going take up a fraction of what I need to do over 3 years, I wouldn't."

Face-to-face or Online (and why): Face-to-face

- "I hate online courses; it's just not my learning style. I need to interact with people."

GIS&T KAs

1. Analytical Methods
2. Cartography and Visualization
3. Geographic Data
4. Conceptual Foundations
5. GIS & Technology and Society
6. Data Manipulation
7. Design Aspects

Irrelevant: Data Modeling, Geocomputation, and Organizational and Institutional Aspects

IDR Challenges

1. Problems Being at the Interface Between Disciplines
2. Lack of Local Level Management

3. Difficulties Related to Collaborating with other Disciplines
4. Time Constraints

Irrelevant: Lack of Opportunities for People, Personality Conflicts, Intransigence from Current Institutional Structures, and Licencing and Ownership Ambiguities

- "Language - what does that mean in your discipline vs. what does that mean in another discipline and understanding... That's frequently an issue."
- "Time - not having enough time to understand the respective disciplines, concepts that they have and way in which they do things, talk, glossaries, thesaurus..."

IDR Solutions

1. Build Relationships
2. Increase Funding Opportunities and Adapt Existing Ones for Interdisciplinary Research

Irrelevant: Provide Training on Technical and Supplemental Skills, Include Senior Staff and Interested Parties, Incorporate Effective Management Practices to Construct Clear Objectives and Evaluation, Incentivise Interdisciplinary Research with Support and Rewards, Establish an Institutional Structure that Prioritises Interdisciplinary Research, Discourage "Disciplinary Selfishness"

Utilised: Build Relationships

- "Spend more time in the early stages of the project learning about the different methodologies from different disciplines, language, developing a glossary of terms and explanations so that people understand when they're talking about X this is what they mean."
- "'Relationships' is the key... Because when you build relationships, the lines of communication are open, when the lines of communication are open you build understanding between various parties within an interdisciplinary project and that's where the learning takes place."

Participant C

Home Discipline: Sociology

GIS Used: Google Maps, ArcGIS, R, QGIS

Search Options Used: Google, Ask for Help, Short Course (UCL), Online Tutorials, YouTube

- "A lot of them were blogs - step by step on 'how to do X' blog entry on 'mapping this using R'... I wouldn't exactly follow it because I wouldn't download the test data, I would actually use my data and see if it works... Try that, didn't work, and then start thinking about it and tweaking it to make it work for my thing."

Interested in a Short Course: Yes

Face-to-face or Online (and why): Face-to-face, if at UCL and at a conducive time, but if offered in a different location, then online would be better (to save travel costs and do in her own time).

GIS&T KAs

1. Geospatial Data
2. Data Manipulation
3. Analytical Methods
4. Design Aspects
5. Cartography and Visualization
6. GIS&T and Society
7. Conceptual Foundations

Irrelevant: Geocomputation, Organizational and Institutional Aspects, Data Modeling

- "I do not even know what that means [Geocomputation]; it sounds very science-y."
- Most make sense, others are "Big Words" (sub-points help); generic and vague, but meant to be so they can be fit to purpose

IDR Challenges

1. Lack of Local Level Management

2. Difficulties Collaborating with Other Disciplines
3. Personality Conflicts
4. Licencing and Ownership Ambiguities
5. Time Constraints

Irrelevant: Problems Being at the Interface Between Disciplines, Intransigence from the Current Institutional Structures, Lack of Opportunities for People

- "Get someone properly managing the project; I think that would've been the number one thing. I think, get someone with more seniority. Someone either with seniority or just some sort of managerial experience or know how to check up on the project, tie everything back to the original project goals, make sure everyone's getting along fine, and everyone's doing what they're supposed to be doing and they don't have any problems. Yes, definitely better management would've helped."
- "Licencing and Ownership Ambiguities - keep a paper trail."
- Personality conflicts can be extremely damaging, as they can damage personal relationships that can create a negative impact on the work

IDR Solutions

1. Incorporation Effective Management Practices to Construct Clear Objectives and Evaluation
2. Discourage "Disciplinary Selfishness"
3. Provide Training on Technical and Supplemental Skills
4. Build Relationships with Members of the Group
5. Include Senior Staff and Interested Parties

Irrelevant: Incentivise Interdisciplinary Research with Support and Rewards, Increase Funding Opportunities and Adapt Existing Ones for Interdisciplinary Research, Establish an Institutional Structure that Prioritises Interdisciplinary Research

Utilised: Include Senior Staff and Interested Parties

- "I feel like the 'Incorporation Effective Management Practices to Construct Clear Objectives Evaluation' would automatically do the 'Discourage "Disciplinary Selfishness"', because it'd be like 'Look, this is a project as a whole, it can only happen if we both do these things and this is how they're going to interact.' rather than doing it in a factory way of like 'you are the sensor people and you are the social science people, work independently and eventually they will come together.' because that doesn't happen, right? You need to be working together the whole time for it to be truly collaborative and interdisciplinary.'

- Outside arbitrators may have been useful.

Participant D

Home Discipline: Anthropology

GIS Used: ArcGIS, QGIS, Community Maps, Sketchup (a long time ago)

- "QGIS, which was the one I used; A. because it was free and I found it [QGIS] a lot more easier to use because it was kind of very basic, but was also used ArcGIS, especially with the historical data because that was quite in-depth, lengthy layer files and Quantum just didn't have the balls [to process it]."
- "It was quite simple, but that meant you couldn't go too complicated. I couldn't work out how to do anything more complex than mapping land use. The ArcGIS was much better for the more in-depth work [?]...but I would lean towards QGIS for entering data."
- Defines GIS as something that is editable and so Google Maps is not a GIS [think about the definition of a GIS]
- Felt disconnected from the data and its purpose, as was involved in data entry but not analysis

Search Options Used: Ask for Help (1), Google (2), YouTube (3), Book (4), Forums (2; part of Google [wouldn't post]), Software Help (4; as helpful as the book)

- "I also had a book, a text book, but I didn't find that particularly helpful because it was all the foundations and understanding. I just wanted to know 'how does A connect to B?'"
- "I would generally put whatever software I was using [as a keyword] first, so if it was using QGIS, put that in first, and I knew a few more technical terms at the time, I wouldn't have known 'digitisation', though, I was thinking, I'd put the task I was looking to do, say, 'enter point information how'. That's kind of the way I would put it. Always put in the software; the answer will come back using the software that you use and it'll also be in probably layman's terms so that I understand it."

Interested in a Short Course: Yes

Face-to-face or Online (and why): face-to-face

- "When you're learning something from scratch, a person is so much better to teach you because they can bend and flex with your issues and your style of learning."

GIS&T KAs

1. Cartography and Visualization
2. Geospatial Data
3. GIS&T and Society
4. Data Manipulation
5. Conceptual Foundations
6. Analytical Methods
7. Geocomputation
8. Data Modeling
9. Design Aspects
10. Organizational and Institutional Aspects

- Vague words as well as some big ones, but makes sense; recognises many of these (sub)aspects were touched upon within the project, though not all personally endeavoured.
- "I don't even know what some of these 'Geocomputations' mean!"
- "'Fuzzy Sets' - what's that even mean?"
- "'Triangulated Irregular Networks' - that's just hokum, abra kadabra voodoo, that is."

IDR Challenges

1. Lack of Local Level Management
2. Personality Conflicts
3. Difficulties Collaborating with Other Disciplines
4. Licencing and Ownership Ambiguities
5. Problems Being at the Interface Between Disciplines
6. Time Constraints
7. Lack of Opportunities for People
8. Intransigence from the Current Institutional Structure

- Management and personality conflicts largely contributed to and fuelled other problems. Conflicting views on direction and personal communication breakdown.
- "There wasn't a lot of collaboration, it was more like divvying up of jobs. Even if they're not really to your specialty, you divvied up the job and you had to do it. "
- "'Difficulties Collaborating with Other Disciplines', because of lack of familiarity with my discipline. Like I said, Anthropology, the way they assumed that Ethnography could be done, based on land use, and I kept wanting to change it and shake it up and like 'No that's not quite how I'd be doing this', if I had any choice I would not be doing this this way. I'd still be using GIS but I would be doing it in a different manner, but this is the way that you want to do it - and I found that frustrating."
- Time Constraints not just an interdisciplinary challenge

IDR Solutions

1. Discourage "Disciplinary" Selfishness
2. Build Relationships with Members of the Group
3. Incorporate Effective Management Practices to Construct Clear Objectives and Evaluation
4. Include Senior Staff and Interested Parties
5. Provide Training on Technical and Supplemental Skills
6. Establish an Institutional Structure that Prioritises Interdisciplinary Research
7. Increase Funding Opportunities and Adapt Existing Ones for Interdisciplinary Research
8. Incentivise Interdisciplinary Research with Support and Rewards

Utilised: Provide Training on Technical and Supplemental Skills (more could've been offered), Increase Funding Opportunities and Adapt Existing ones for Interdisciplinary Research, Build Relationships with Members of the Group (away days; could've been done more frequently), Incorporate Effective Management Practices to Construct Clear Objectives and Evaluation (certain amount of repetition, though)

- Bring Solutions ranked 6-8 higher up for more effective IDR
- Felt a disconnection from the data and analyses and would’ve felt more vestige in the project if had been involved more, though contingent upon time.

- "I think the beginning of the project is very important and should be structured incredibly clearly. Everyone should be given training in all the subjects they're working with."

Participant E

Home Discipline: Archaeology

GIS Used: Open Street Map, Wheel Map, Community Maps, Manifold, Google My Maps

- "Starting off in Manifold was a bit sort of hard-core really. It's a lot easier to start with something like, say, Google Maps, which has got really simple tools, because I did find the Manifold interface quite difficult."
- "I did find that [using Manifold] difficult to begin with, just because of the icons. Those tiny little stars with little dots and things next to them, it was just like 'wow...'"

Search Options Used: Online tutorials (1), (Online) Help (but it's huge; didn't find it user friendly) (1), Ask someone (3, but most helpful), Internet Search (Google, YouTube) (2)

- "The good thing about the tutorial as well, rather than just kind of wandering around in it by myself, the course was actually really good, because it demonstrated the power of the tools, really. So I like that."
- "You can just spend ages wandering around and not knowing what you're doing, and actually that can be very negative because then you can get frustrated and daunted and feel a bit of an idiot. Whereas if you just, say, ask somebody for help, then, you know, they can show you how to do something and it can be much more positive experience."
- links, spreadsheet, Manifold [mention the GIS package]; refer to course notes/online tutorial to find the terms that can help to build the search
- "I'd start with a manual or course tutorial documentation... That would help me to know, if I was looking for search terms that would help me to find the search terms that I might want to use if I needed to go and use online resources."
- "The most effective thing to do would be to ask somebody in the first place, but I'd want to have a go first. If you can work things out for yourself, it's more effective for learning, I think."

Interested in a Course: Yes

Face-to-face or Online (and why): 50/50

- "The good thing about face to face is that if you hit a problem, you can get it sorted out straight away."

- "If you were working with other people that would be helpful. When did the Manifold course, Rebecca and I did it together, so we were able to share the learning, in a way... working it out between us, which I quite liked."

GIS&T KAs

1. Design Aspects, Conceptual Foundations and Data Modeling
2. Cartography and Visualization and Geospatial Data
3. GIS&T and Society

Irrelevant: Data Manipulation, Geocomputation, Analytical Methods, Organizational and Institutional Aspects

- Some wording too jargon-y; KAs were grouped, as interviewee believed topics fed into each other
- "I think that's is really important because that's the power of the map, the Cartography and Visualisation, and I can see that's very complex in terms of the way people receive information and lots of issues, as well, around what you visualise, making things simple for people to understand."
- "Words like 'Genetic Algorithm' make me want to run away."
- "'Genetic Algorithm' doesn't really mean anything to me... I have no idea what that means!"
- "I understand those words, I wouldn't know how I would apply those things because of never done them. Or maybe I have but maybe I don't know I've done it."
- "'Geocomputation' is a bit of a mouth-full"

IDR Challenges

1. Problems Being at the Interface Between Disciplines, Lack of Opportunities for People and Intransigence from Current Institutional Structures
2. Personality Conflicts, Lack of Local Level Management and Licencing and Ownership Ambiguities
3. Difficulties Related to Collaborating with other Disciplines and Time Constraints

- Again, topics were grouped as interviewee believed topics fed into each other

- "The main thing that springs to mind, and I see this historically, the conflict between quantitative and qualitative research. People who do quantitative research... they don't really give the same value to qualitative research and that can be a challenge."
- "Because I worked across the two disciplines, I found myself falling down a bit of a hole in the middle, really. The people in Geography didn't really get what I did and the people in Archaeology didn't think I was an Archaeologist... To be honest, that's one of the reasons I got out of academia."

IDR Solutions

1. Build Relationships with Members of the Group and Discourage "Disciplinary Selfishness"
2. (All others)

Irrelevant: (None)

Utilised: Build Relationships with Members of the Group

Suggested change: A solution to focus on and increase diversity for incorporation of multi-gender/cultural/etc. perspective

- Topics not so much grouped, but rather 1 acknowledges what was and what could have been personally implemented, 2 acknowledges how all topics suggested are indeed relevant at different levels by different people involved on the projects
- "The challenge definitely around the culture of academia. Changing that is actually quite difficult."
- "It's [Interdisciplinary Research Issues] just to do with communication. As the issues arise, actually dealing with them and communicating with people - that's really, I think, the only way."
- "Some training in writing funding applications would help in that [Interdisciplinary Issues]."

Participant F

Home Discipline: Architect

GIS Used: QGIS, Garmin GPS, Google (KMZ)

Search Options Used: Online Tutorials (2), Email a friend (1), Twitter (4), QGIS Forums, Scouring the Web (Google) (3)

- "I would go, 'shapefile, misaligned, problems, CRS' just to see what would come up. I'd have a fair idea, I've already used some of the terminology, but to be honest I thought it was much more difficult to find a clear answer to it. I think it could be much clearer."
- "I'd say the online tutorials were really useful."
    - Harvard (platform customised for architects)
- "The QGIS Manual, I couldn't touch. I felt it was far too protracted. You know, it's this size; whereas I was able to get the things I wanted to done in a number of slides on the Harvard website. So that was really useful to me."
    - Technically "Heavy"
- "I'd say Twitter, then, was quite useful. It opened up, a couple of people came forward and offered to help."

Interested in a Course: Yes, but within the limitations of the project it wouldn't have been possible. (location, hardware difficulties and cost)

Face-to-face or Online (and why): face-to-face

- "You can ask people if you've got a question, you can just ask someone directly. I'd much prefer that."
- "As a non-user prior to using it, you're kind of put off by the amount of technical bumpf and language around it that it would almost dissuade you almost, like put you off, you know? So I definitely think, having been out the end, I'd say, it's much easier to use, but the earlier stages, there would definitely be a level of anxiety about having to try to overcome that."
- Some self-deprecation due to not knowing some things

GIS&T KAs

1. GIS & Technology and Society
2. Cartography and Visualization

3. Conceptual Foundations
4. Geospatial Data
5. Data Modeling

Irrelevant: Design Aspects, Geocomputation, Analytical Methods, Organizational and Institutional Aspects, Data Manipulation

- Kind of sound the same; a little 'unfriendly'

IDR Challenges

1. Difficulties Related to Collaborating with other Disciplines
2. Lack of Local Level Management
3. Time Constraints
4. Licencing and Ownership Ambiguities
5. Intransigence from Current Institutional Structures
6. Personality Conflicts

Irrelevant: Problems Being at the Interface Between Disciplines, Lack of Opportunities for People

- "I don't know if I'd really call it interdisciplinary. Maybe that's my lack of full understanding of what interdisciplinary is."
- Many question whether the work is 'interdisciplinary' (when it very much is) [why?]
- "'Difficulties Related to Collaborating with other Disciplines', this is lack of a familiarity of a new discipline's language and culture or vice versa - that's ALWAYS an issue..."

IDR Solutions

1. Provide Training on Technical and Supplemental Skills
2. Build Relationships with Members of the Group
3. Incorporate Effective Management Practices to Construct Clear Objectives and Evaluation
4. Discourage 'Disciplinary Selfishness'
5. Include Senior Staff and Interested Parties
6. Increase Funding Opportunities and Adapt Existing Ones for Interdisciplinary Research

Irrelevant: Incentivise Interdisciplinary Research with Support and Rewards, Establish Institutional Structure that Prioritises Interdisciplinary Research

- "This [Provide Training on Technical and Supplemental Skills] kind of resonates just as a researcher in general, about the kind of people who were particularly magpies about the information that they have and the power that they hold within that information. It was important to know that the people who were computer savvy were sitting alongside people who weren't, and they had to train one another."

Participant G

Home Discipline: Evolutionary Biology (Marine Biology)

GIS Used: ArcGIS, QGIS

Search Options Used: Google (2), Desktop Help (3), Ask an Expert (1), Esri Online courses, forums, YouTube (didn't use it then but would use it now)

- Would search using GIS terms he'd heard [very specialist terms] (spatial correlation, heatmap, etc.)

Interested in a course: Yes

Face-to-face or Online (and why): Would've preferred face to face, back then, but now, definitely online

- "I used to think that if I had problems or questions, being in a face to face setting would allow me to get the answers to those questions from an expert quickly. What I've discovered now is that through online learning, first of all, before the questions arise, having the material presented in such a way so that I can, say, pause the video and really kind of think carefully about what was just said before being presented with additional material is just crucial. You can't pause an instructor, but you can pause a video. That's just really important for me in terms of learning. But then also being able to articulate a question in an online forum that an instructor would read is less intimidating than approaching an instructor, raising my hand and admitting my ignorance in person."
- non-descriptive error messages are frustrating

GIS&T KAs

1. Cartography and Visualization
2. Analytical Methods
3. Geospatial Data
4. Design Aspects
5. Organizational and Institutional Aspects
6. Data Manipulation
7. GIS & Technology and Society
8. Geocomputation

Irrelevant: Data Modellng, Conceptual Foundations

- "Why is Resource Planning Under Design Aspects?"
- "Fuzzy Sets, that's something I don't understand."
- "Everywhere we work we're trying to do some outreach an education, do some capacity development, training, and so on, on the ground..."

IDR Challenges

1. Licencing and Ownership Ambiguities
2. Problems Being at the Interface Between Disciplines
3. Personality Conflicts
4. Time Constraints
5. Difficulties Related to Collaborating with other Disciplines
6. Lack of Local Level Management
7. Intransigence from Current Institutional Structures, Lack of Opportunities for People

IDR Solutions

1. Incentivise Interdisciplinary Research with Support and Rewards
2. Increase Funding Opportunities and Adapt Existing Ones for Interdisciplinary Research
3. Provide Training on Technical and Supplemental Skills
4. Establish Institutional Structure that Prioritises Interdisciplinary Research
5. Build Relationships with Members of the Group
6. Incorporate Effective Management Practices to Construct Clear Objectives and Evaluation
7. Include Senior Staff and Interested Parties
8. Discourage 'Disciplinary Selfishness'

- "People weren't going to do this work without tons of funding. They'd rather work in their own siloed way and not do interdisciplinary work, but when there was a million dollars dangled in front of them, they were more than happy - so that was key."

- "We were forced to do this [Incorporate Effective Management Practices to Construct Clear Objectives and Evaluation] by our funders and I think that it was extremely important."
    - needed a database to share information; once that was made, papers started to get published

Participant H

Home Discipline: Psychology

GIS Used: None (people have created stuff for her; maps for informed decision making)

Search Options Used: None

- Talk it out, draw figures; visual communication

Interested in a course: Yes, a couple of days for basic competence

Face-to-face or Online (and why): Face-to-face, it's easier to commit the time to it and there's someone there to answer questions (but there are advantages to online)

GIS&T KAs (no picture)

1. Cartography and Visualization

Irrelevant: Conceptual Foundations, Geospatial Data, Data Modeling, GIS&T and Society, Data Manipulation, Geocomputation, Analytical Methods, Organizational and Institutional Aspects, Design Aspects

IDR Challenges (no picture)

1. Difficulties Related to Collaborating with Other Disciplines, Lack of Opportunities for People, Time Constraints, Personality Conflicts, Licencing and Ownership Ambiguities, Problems Being at the Interface Between Disciplines

Irrelevant: Lack of Local Level Management, Intransigence from Current Institutional Structures

- "The main thing is people having different knowledge, different expertise, and how they can communicate it to each other. As a professor, if I'm hiring a GIS person to work on a project, can I trust them to do it right, because I don't necessarily have the knowledge to know its right."
- doesn't feel some these challenges (e.g. personality conflicts, time constraints) are specific to interdisciplinary (can happen anywhere)
- "Sometimes the same word means different things in different disciplines or it has different connotations... There's a lot of learning each other's terminology. 'Oh

when you say this you mean this, and when we say this we mean that.' There's a lot of that, so if that's what you're trying to get at here I think that's really a big deal."

IDR Solutions (no picture)

1. Provide Training on Technical and Supplemental Skills, Incentivise Interdisciplinary Research with Support and Rewards
2. Establish an Institutional Structure that Prioritises Interdisciplinary Research, Increase Funding Opportunities and Adapt Existing Ones for Interdisciplinary Research, Include Senior Staff and Interested Parties, Build Relationships with Members of the Group

Irrelevant: Incorporate Effective Management Practices to Construct Clear Objectives and Evaluation, Discourage 'Disciplinary Selfishness'

- again, doesn't feel some of these are specific to interdisciplinary research

Participant I

Home Discipline: Library Sciences

GIS Used: (Almost exclusively) ArcGIS for Desktop

- "[ArcGIS] Server is a huge problem, because I'm not an enterprise Geodatabase administrator and the Library's central IT department, they're not really interested in supporting an enterprise class Geodatabase for me, or installing [ArcGIS] Server. I've been here for 5 years and the first things I said was 'Where's the GIS Server?' and they'd all fallen apart because there was nobody in the library anymore who knew how to use them; they had all left at the end of grant-funded projects... They just turned off the servers one by one because they didn't actually know what they did. Millions and millions of dollars of grant funded stuff that just became obsolete because there was nobody taking care of it, there nobody upgrading it, there was nobody optimizing the databases."
- "We're 15 years behind, but 15 years ago, we were cutting edge."
- support for social scientists to have a need for the technology but don't have the skills

Search Options Used: Ask an Expert, Google (most effective)

- "There's no place, other than to your peers, to articulate 'I think I want to do this, but I'm not quite sure how to go about it.' There is no system that you can ask that question of."
- Search for things like "ArcGIS On mouse click" [uses name of GIS in search term]
- "When we're looking for data... I'll say 'use your keyword search, but then just add shapefile'... you won't get so many web pages about data, you'll start to get pages WITH data."
- JASIST (Journal of the American Society for Information Science and Technology) - Information Seeking Behaviour
- "Students, if they want to do something more broad, they go out for a couple of days and attempt to find data, and then they flail around and then they're like 'Ah, I'll just design a project around the data that's available to me.' instead of coming up with a research question and finding the data that's appropriate to their research question."
- "Regardless of whether it's a short course online or face-to-face, it's applying the new knowledge to my own personal projects, that's where I get stuck and that's

where I see undergraduates and even professional scholars, that's where I see them flail."

- finding the data you need is such a problem; compounded with not know what to ask to find the answers to the questions you have

Interested in a course: Yes

Face-to-face or Online (and why): Pick the online due to time constraints, but prefer face-to-face

GIS&T KAs

1. Cartography and Visualization, Geospatial Data, Analytical Methods, Data Manipulation
2. Data Modellng, Geocomputation, Organizational and Institutional Aspects, GIS & Technology and Society, Conceptual Foundations
3. Design Aspects

1 = Core of GIS, 2 = Important, but doesn't really see the difference between them (irrelevant?), 3 = Covers Everything (Top)

- "They're all kind of jargon-y... Just slapping 'Geo' at the beginning of something doesn't necessary help anybody."

IDR Challenges (no picture)

1. Intransigence from the Current Institutional Structures, Time Constraints
2. Licencing and Ownership Ambiguities, Lack of Local Level Management, Personality Conflicts

1 = Top, 2 = Secondary

Irrelevant: Problems Being at the Interface Between Disciplines, Lack of Opportunities for People, Difficulties Related to Collaborating with other disciplines

- Not Jon, but one of the interdisciplinary researchers involved on his project would always denigrate their expertise in GIS

IDR Solutions

1. Build Relationships with Members of the Group, Incorporate Effective Management Practices to Construct Clear Objectives and Evaluation
2. Provide Training on Technical and Supplemental Skills

Irrelevant: Increase Funding Opportunities and Adapt Existing Ones for Interdisciplinary Research, Discourage 'Disciplinary Selfishness', Include Senior Staff and Interested Parties, Establish an Institutional Structure that Prioritises Interdisciplinary Research, Incentivise Interdisciplinary Research with Support and Rewards

1 = Top, 2 = Secondary

- "People don't appreciate the financial overhead of some of these collaborations."

Participant J

Home Discipline: Ecology

GIS Used: QGIS, ArcGIS

- "QGIS seems more user friendly; all the buttons seem to make sense."
- "It [QGIS] did crash a lot."
- "There seemed to be more functionality through plugins, and the menus make more sense. It seems to be added to by a lot of people, where, with Arc[GIS] it expects you to figure it out and it seems more intense."

Search Options Used: Google, Forums (though largely unhelpful), Expert Help (most helpful), YouTube videos (more helpful than the forums), Books (conceptual, no practical help)

- "I didn't know what to search for; it might've been called something else and there might've been a video for it, but I might not have found it because I didn't know the terminology... That might have gotten in the way of finding the help online."
- "How to get information from polygons to point QGIS" [uses name of GIS in search]
- "The frustrating thing is that I think there's help out there for everything that you want to do, but even if you put in all the terms you can think of, it still might not come up, and it takes ages searching through things that are irrelevant, but you're not sure if the things you're looking at is relevant or not, because you're not sure what it is you're trying to do. Sometimes you spend an hour trolling through forums think 'I'm not sure if this is going to help me, or not.'"

Interested in a course: Yes

- "I think if I knew the basics of GIS, that I can use 'this' to do 'this', I could've planned out my project a bit better."

Face-to-face or Online (and why): No immediate preference, but materials must be clear; maybe combo (but preference for face-to-face)

GIS&T KAs

1. Analytical Methods
2. Cartography and Visualization

3. Conceptual Foundations
4. Data Modellng
5. Data Manipulation

Irrelevant: Geospatial Data, Geocomputation, Organizational and Institutional Aspects, Design Aspects, GIS & Technology and Society

- "I don't really understand a lot of them [words used]... A lot of it's quite jargon-y."

IDR Challenges

1. Difficulties Related to Collaborating with other Disciplines
2. Time Constraints
3. Intransigence from Current Institutional Structures
4. Lack of Local Level Management
5. Personality Conflicts
6. Problems Being at the Interface between Disciplines

Irrelevant: Licencing and Ownership Ambiguities, Lack of Opportunities for People

IDR Solutions

1. Include Senior Staff and Interested Parties
2. Provide Training on Technical and Supplemental Skills
3. Build Relationships with Members of the Group
4. Incorporate Effective Management Practices to Construct Clear Objectives and Evaluation
5. Establish an Institutional Structure that Prioritises Interdisciplinary Research
6. Increase Funding Opportunities and Adapt Existing Ones for Interdisciplinary Research
7. Incentivise Interdisciplinary Research with Support and Rewards
8. Discourage "Disciplinary Selfishness"

- "I could've had a better team relationship which would've provided some support, and training would've been helpful."

Participant K

Home Discipline: Molecular Biology

GIS Used: QGIS, R

Search Options Used: Google, Stack Exchange (didn't post/answer), Expert help, YouTube (but prefer text), Tutorials

- "Create Centroid QGIS" [uses vocab]
- "It'd be nice to know what they all [specialist terms] mean."
- "Sometimes the difficulty is knowing the right keyword. I know what I want to do, but if I don't know the keyword I need so I can't find what I'm looking for."

Interested in a course: Yes, if had the time

Face-to-face or Online (and why): Face-to-face for immediate response to questions

GIS&T KAs

1. Conceptual Foundations
2. Data Manipulation, Analytical Methods, Geospatial Data, Cartography and Visualization
3. Organizational and Institutional Aspects, Design Aspects, Data Modeling
4. GIS & Technology and Society, Geocomputation

IDR Challenges

1. Time Constraints, Difficulties Related to Collaborating with Other Disciplines
2. Licencing and Ownership Ambiguities, Intransigence from Current Institutional Structures
3. Lack of Local Level Management, Personality Conflicts, Problems Being at the Interface Between Disciplines
4. Lack of Opportunities for People

1 = faced in the project; 2 = would be more relevant in larger; 3 = personal philosophy; 4 = could be relevant, but not applicable in this case

- Feels that these are largely general and could apply on any project (not just IDR ones)

IDR Solutions

1. Build Relationships with Members of the Group, Provide Training on Technical and Supplemental Skills
2. Include Senior Staff and Interested Parties, Incorporate Effective Management Practices to Construct Clear Objectives and Evaluation
3. Increase Funding Opportunities and Adapt Existing Ones for Interdisciplinary Research, Incentivise Interdisciplinary Research with Support and Rewards, Discourage "Disciplinary Selfishness", Establish an Institutional Structure that Prioritises Interdisciplinary Research

1 = would've been good; 2 = utilised; 3 = In a larger context possibly

- Sometimes trouble with language
- Blaming self for misunderstandings (personal and with tech)

Appendix 4 - Learning Diaries

A.4.1 Learning Diaries Scans

(Please see /Learning_Diaries)

Appendix 5 - GL4U: Relevant and Non-Relevant Contexts

A.5.1 GL4U Code

(Please see /GL4U_Relevant_and_Non-Relevant_LACs/tutorial)

A.5.2 Advanced Custom Fields – Custom Fields and Values for Each Context

(Please see files in /GL4U_Relevant_and_Non-Relevant_LACs/Advanced_Custom_Fields)

A.5.3 Survey Questions – Post Practical 1 Survey

- Which learning style did you use to learn GIS that is relevant to this survey? [Online or Face-to-Face]
- Which context did you learn GIS in as part of this exercise?
- Roughly how long did it take for you to complete all the lessons or the resulting output?
- Prior to this exercise, what was your level of experience with GIS?
- Why did you decide to take a GIS class or be a part of a GIS learning activity?
- How did you feel about "GIS Lessons For You" or the learning activity you went through in regards to it helping you learn what you wanted to learn about GIS?
- What did you want to achieve through learning GIS? What tasks do you want to accomplish?
- Do you feel the context in which you learned the lessons positively or negatively affected your learning experience? Why do you believe it had this effect?
- If you had not taken this class and needed to learn to use a GIS, how would you go about learning it?
- Please provide your email address
- What would you identify as your home discipline (e.g. Anthropology, Psychology, etc.)?

(For results, please see /GL4U_Relevant_and_Non-Relevant_LACs/Practical_1_Survey.xlsx)

A.5.4 Survey Questions – Post Follow-Up Practical Survey

- Please provide your email address [this was to link their responses to those from the survey they had previously completed]
- Please input how long it took for you to complete the resulting output [the Story Map]

- Do you feel the context in which you learned the lessons [Medieval Swansea, Water Access in Lima, Generic] positively or negatively affected your learning experience? Why do you believe it had this effect?

(For results, please see /GL4U_Relevant_and_Non-Relevant_LACs/Follow-up_Survey.xslx)

A.5.5 Follow-up Sessions – Notes and Recordings

(Please see files in /GL4U_Relevant_and_Non-Relevant_LACs/Notes_and_Recordings)

A.5.6 DPU Applications with GIS – Survey Questions and Responses

- How was GIS used in your group? Did everyone do a bit of work with it or was work delegated to a designated member of the group? What was the reasoning for the work with GIS being done this way?
- What was your perception of ArcGIS Online in comparison to QGIS? Did you or your group use either (or both) as part of the work undertaken in Lima and what was your reasoning for using (or not using) them?
- Did "GIS Lessons for You" (e.g. the lessons on ArcGIS Online) help you feel confident in using GIS, in general? Why do you believe this was (or was not) the case?
- Did the concepts you learnt in GIS training cover everything that you needed to do with GIS in the field? Which GIS concepts that were covered were not relevant (if any) and why? Which GIS concepts do you feel should be added and why?
- Do you feel that the training on GIS and your collective understanding of it was able to provide a common platform for dialogue between your group members / disciplines? Do you feel it helped with group cohesion? Please elaborate on why you believe this was (or was not) the case.
- On reflection, if you were to have the chance again, would you have taken the GIS training to learn what you needed to learn about GIS or would you rather have learnt it informally (e.g. through Google searches, YouTube videos, etc.), searching for what you wanted to learn, as needed? In regards to your time, do you feel the learning GIS concepts through training or learning them informally is/would be more efficient? Please elaborate on why you believe this to be the case.

Further question asked if the group did not use GIS:

- As you did not use GIS in your work, what was the group's reason for not doing so? Is there anything that could have been done that would have encouraged you or your group to have used it?

(For group representative responses, please see files in /GL4U_Relevant_and_Non-Relevant_LACs/DPU_Responses)

Appendix 6 - GL4U: Formal and Informal Learning Approaches

A.6.1 Recruitment Survey Questions and Responses

1. Name (required) [open text]
2. Email (required) [open text]
3. Are you over the age of 18? (Please note: if you are under the age of 18, you will not be eligible to participate in this study) [Yes, No]
4. What would you identify as your academic disciplinary background (e.g. Sociology, Photography, etc.)? (required) (Please note: if your disciplinary background is one that would commonly use GIS [e.g. Geography, Geoinformatics, etc.] you may not be eligible to participate in this study) [open text]
5. Do you have any experience with interdisciplinary research (e.g. research involving people from two or more disciplines, combining methodologies to address a research question)? [Yes, No]
    a. If Yes, please describe any relevant experience in the following box: [open text]
6. What is your current level of experience using Geographic Information Systems (GIS) (e.g. ArcGIS, QGIS, etc.)? (Please note: to be eligible for this study, you must have little/no experience with GIS) [No experience at all, Very little experience, Basic experience, Intermediate experience, Advanced experience]
    a. If your experience is anything other than no experience at all, please describe your experience in the box below (this is to ensure you are eligible for the study): [open text]
7. How interested are you in learning GIS? [Not interested at all, Somewhat interested, Moderately interested, Very interested, Highly interested]
    a. Please describe below the reason for your selection of level of interest in learning GIS: [open text]

(For results, please see /GL4U_Formal_and_Informal_LECs/Recruitment_Survey.xslx)

A.6.2 Workshop Follow-up Survey Questions and Responses

In the survey, the questions asked were as follows:

1. Name (required) [open text] (This would be used to match their responses in the follow-up survey to their responses in the initial recruitment survey)

2. Do you feel that you were able to build a basic understanding of GIS during the workshop? [Yes, No]
    a. Please elaborate in the box below: [open text]
3. Now that you have completed the workshop, how motivated are you to continue using GIS? [Not motivated at all, Somewhat motivated, Moderately motivated, Highly motivated, Extremely motivated]
    a. Please elaborate in the following box on why you may or may not feel motivated to continue to use GIS: [open text]
4. GIS curricula, such as the Geographic Information Science & Technology Body of Knowledge (GIS&T BoK), outline Knowledge Areas (KAs) that can be used to form programmes for teaching GIS, which are tailored to Geography/Geoinformatics students. However, it is questionable if these adequately cover topics of interest to those coming from other disciplines that may use GIS. Now that you have learned a bit about GIS, imagine how you would use it within your own discipline. Given the table below, which describes the Knowledge Areas from the GIS&T BoK, please select whether you would consider these to be relevant or not to work you would potentially do with GIS.
    a. Querying and analysing geospatial data in a GIS [Relevant, Not Relevant] (corresponds to KA Analytical Methods)
    b. Designing and creating maps in a GIS [Relevant, Not Relevant] (corresponds to KA Cartography and Visualization)
    c. Questioning the spatial relationships or philosophical perspectives of GIS data [Relevant, Not Relevant] (corresponds to KA Conceptual Foundations)
    d. Using GIS to prepare maps at different scales or convert map data from one format to another [Relevant, Not Relevant] (corresponds to KA Data Manipulation)
    e. Structuring and managing data in a GIS database [Relevant, Not Relevant] (corresponds to KA Data Modeling)
    f. Planning the system design and deployment of a GIS [Relevant, Not Relevant] (corresponds to KA Design Aspects)
    g. Creating algorithms or modelling processes which take into account uncertainty inside a GIS [Relevant, Not Relevant] (corresponds to KA Geocomputation)
    h. Creating new data inside of a GIS and/or using satellite imagery inside of a GIS [Relevant, Not Relevant] (corresponds to KA Geospatial Data)

i. Being concerned about the legal aspects or ethics of the data in a GIS [Relevant, Not Relevant] (corresponds to KA GIS&T and Society)
j. Formatting GIS data in a way that improves its usability by others [Relevant, Not Relevant] (corresponds to KA Organizational and Institutional Aspects)
k. Please outline how you could see yourself using GIS and elaborate in the following box on why you feel the Knowledge Areas may or may not be relevant to potential work you would do: [open text]

5. For issues encountered when attempting to learn GIS, please select the effectiveness of each of the methods you may have utilised:
    a. Internet search [Not very effective, Effective, Very effective, N/A]
    b. Watch a video [Not very effective, Effective, Very effective, N/A]
    c. Follow a tutorial [Not very effective, Effective, Very effective, N/A]
    d. Software help manual [Not very effective, Effective, Very effective, N/A]
    e. Ask a more experienced person [Not very effective, Effective, Very effective, N/A]
    f. Post on a forum [Not very effective, Effective, Very effective, N/A]
    g. In the following box, please list any other methods utilised that weren't listed and how effective you feel they were in answering your questions (not very effective, effective, very effective) [open text]
6. If you needed to search for information, how did you go about formulating your search keywords to search for information on how to do what you needed to do in the GIS? [open text]
7. As you've gone about learning how to create a Story Map, how do you feel about the GIS specific language you may have encountered (e.g. digitisation, symbology, etc.)? [open text]
8. As you went through the workshop, you attempted to complete certain tasks in ArcGIS Online (either through training materials provided or information sought out). Please select all tasks you were able to complete: [tick boxes]
    a. Be able to move around and zoom in/out on the map
    b. Change the basemap of the map
    c. Search for Layers and add a layer to the map
    d. Add Layer from File (2 Shapefiles [Zip archive]) to the map and Change Style
    e. Add Layer from Web (KML File) to the map

f. Add a Map Notes Layer to the map and add Map Notes point with Title, Description, image URL and Image Link URL
g. Save the map you have created with a Title, Tags and a Summary
h. Share the map you have created with Everyone (public)
i. Create a Web App using the Story Map Series Configurable App (Tabbed layout with Legend)
j. Add text and an image to the text box in the Story Map
k. Save the Story Map and View Live version
l. Were any of these tasks particularly confusing or difficult to do? If so, please elaborate in the following box: [open text]

9. Based upon what you have done, how confidently do you feel that you would be able to create a Story Map again? [Not confident at all, Somewhat confident, Moderately confident, Highly confident, Extremely confident]
    a. Please elaborate in the following box on why you may or may not feel confident in creating a Story Map again: [open text]
10. Did you take part in the formal or informal learning workshop? [Formal Learning Workshop, Informal Learning Workshop]
11. [FORMAL LEARNING WORKSHOP] How long (in minutes) did it take for you to finish the lessons (1-3 & 5) in "GIS Lessons for You"? (Note: If you did not complete it in time, please indicated which lessons you were able to complete) [open text]
12. [FORMAL LEARNING WORKSHOP] How long did it take for you to learn to create the Story Map that was to be created as part of the follow-up activity? (Note: If you did not complete it in time, please say "Did not complete") [open text]
13. [FORMAL LEARNING WORKSHOP] How effective do you feel this formal method (e.g. a structured tutorial) of learning how to create a Story Map was? [Not effective at all, Somewhat effective, Moderately effective, Highly effective, Extremely effective]
    a. Please elaborate on why you do (or do not) believe this method was effective in the box below: [open text]
14. [FORMAL LEARNING WORKSHOP] Which context did you use for the lessons in "GIS Lessons for You"? [Disaster Planning in Seattle, Generic, Medieval Swansea, Water Access in Lima]
15. [FORMAL LEARNING WORKSHOP] Why did you select the context you did? (required) [open text]

16. [FORMAL LEARNING WORKSHOP] Do you feel the context in which you learned the lesson (e.g. Medieval Swansea, Water Access in Lima, etc.) positively or negatively affected your learning experience? [Positively, Negatively]
    a. Why do you believe the context affected your learning of GIS in this way? Please elaborate in the following box: [open text]
17. [FORMAL LEARNING WORKSHOP] If you were tasked to create a Story Map as part of an interdisciplinary project, would you have used a tutorial, like "GIS Lessons for You", to learn how to create one or would you have used a more informal learning approach (e.g. internet searches, videos, etc.)? [Tutorial, Informal Learning Approaches]
    a. Please elaborate on your reasons for choosing the tutorial or informal learning approaches in the box below: [open text]
18. [FORMAL LEARNING WORKSHOP] What is your overall opinion of this workshop and the materials presented in "GIS Lessons for You" for learning to create a Story Map? [open text]
19. [INFORMAL LEARNING WORKSHOP] How long (in minutes) did it take for you to learn to do the tasks to make a Story Map, as given on the information sheet? (Note: if you did not complete it in time, please say "Did not complete") [open text]
20. [INFORMAL LEARNING WORKSHOP] How long (in minutes) did it take you to learn to create the Story Map that was to be created as part of the follow-up activity? (Note: If you did not complete it in time, please say "Did not complete") [open text]
21. [INFORMAL LEARNING WORKSHOP] How effective do you feel this informal method (e.g. searching for information, watching videos, etc.) of learning how to create a Story Map was? [Not effective at all, Somewhat effective, Moderately effective, Highly effective, Extremely effective]
    a. Please elaborate on why you do (or do not) believe this method was effective in the box below: [open text]
22. [INFORMAL LEARNING WORKSHOP] Do you believe the problem domains (e.g. the context) of the materials you found while learning how to do tasks to create a Story Map helped or hindered your ability to learn how to do those tasks? [Helped, Hindered]
    a. Please elaborate in the following box on why you feel this may have been the case: [open text]
23. [INFORMAL LEARNING WORKSHOP] Do you believe a tutorial with lessons using problem domains (e.g. contexts) from your discipline on how to create a

Story Map would've been something you would've used to learn to create a Story Map? [Yes, No]

    a. Why would you use or not use such a resource, if it were made available to you? Please elaborate in the following box: [open text]

24. [INFORMAL LEARNING WORKSHOP] Do you believe such a resource would have been more helpful in helping you learn how to create a Story Map in comparison to the way you've just done it? [Yes, No]
    a. Why do you feel it may or may not have been more helpful? Please elaborate in the following box: [open text]
25. [INFORMAL LEARNING WORKSHOP] What is your overall opinion of this workshop and the materials you found for learning to create a Story Map?

(For results, please see /GL4U_Formal_and_Informal_LECs/Workshop_Survey.xslx)

A.6.3 Workshop Information (Presentation, Signed Consent Sheets, Information Packs, Screen Recordings, Search Histories)

(Please see /GL4U_Formal_and_Informal_LECs/Workshop_Files)

A.6.4 Additional Workshop Findings – Formal Workshop Extra Results

- TABS vs. WINDOWS: 3 participants (33%) used tabs within the same browser window, 5 participants (56%) used tabs to begin with then had two windows side by side and 1 participant (11%) used two windows side by side throughout the workshop
- GL4U – SCREENSHOTS: 3 participants (33%) had difficulty with discrepancies in the screenshots in GL4U due to interface changes
- ARCGIS ONLINE – GENERAL GLITCHES: All 9 participants (100%) experienced some sort of glitch or issue with ArcGIS Online
- ARCGIS ONLINE – TOUR: 1 participant (11%) had selected the "Take a Map Tour" option that was initially available to learn about the map functionality, though they did not follow it all the way through
- ARCGIS ONLINE – FAMILIAR LOCATION: 5 participants (56%), when they first loaded the map, navigated to somewhere that may have been familiar to them (e.g. home, work, etc.)
- ARCGIS ONLINE – OVERVIEW MAP: 2 participants (22%) clicked "locate" instead of "overview map"
- ARCGIS ONLINE – RELOAD: 6 participants (67%) reloaded the map at some point, on purpose or accidentally, and lost unsaved changes as a result

- ARCGIS ONLINE – CHANGING SYMBOLOGY: 3 participants (33%) clicked the symbol under the layer to try and change its symbology
- ARCGIS ONLINE – WEB MAP vs. WEB APP: 1 participant (11%) had difficulty understanding the difference between the web map and web app in Contents, especially as they both had the same name
- ARCGIS ONLINE – GETTING BACK TO INTERFACE: 3 participants (33%) had difficulty getting from the Web App back to the main ArcGIS Online interface and, once they did, would then have to sign back in, as the session variable was not saved in the browser
- SEARCH FOR LAYER: 4 participants (44%) had difficulty when searching for layers in ArcGIS Online, as they had not used the exact layer name or the box was selected to only show layers within the current map extent
- ADD FROM FILE (SHP): 3 participants (33%) were confused about the zipped shapefile, whether to unzip it or not and, if so, which file to add
- ADD FROM WEB (KML) – GENERAL UNDERSTANDING: 2 participants (22%) had difficulty with understanding the KML was a remote resource that simply required the correct URL, rather than downloading the physical file, to add it to the map
- ADD FROM WEB (KML) – SELECT FILE: 3 participants (33%) did not change the drop down when adding the KML layer to be for a KML file, though the layer was still added to the map correctly
- ADD FROM WEB (KML) – DISPLAY GLITCH: 4 participants (44%) experienced an issue with the KML, which referenced an image, not displaying in the correct location in the Story Map
- ADD MAP NOTES LAYER – FROM SEARCH RESULT: 1 participant (11%) added the map note layer from the option given in a search result pop up rather than from the add layer menu
- ADD MAP NOTES LAYER – DIFFICULTIES: 5 participants (56%) experienced issues with add map notes, either with getting in or out of edit mode or due to the "https://" automatically added to the image URL or image link fields
- STORY MAPS – FROM WEBSITE: 1 participant (11%) created the Story Map from the Story Maps website which was discovered as the result of a search, rather than through the ArcGIS Online interface they had been working in
- STORY MAPS – IMAGE AS TAB: 5 participants (56%) had initially added the image that was to be added in the description for the Story Map as a separate tab

- STORY MAPS – EXTRA TABS: 1 participant (11%) had difficulty deleting extra tabs they had created in the Story Map
- WORKSHOP QUESTIONS: 5 participants (56%) asked the researcher or volunteer a question; these were on the image in the Story Map description, creating a web app, where to save files, symbology, glitches, login issues and general GIS guidance

A.6.5 Additional Workshop Findings – Informal Workshop Extra Results

- TABS vs. WINDOWS: 8 participants (73%) used tabs within the same browser window and 3 participants (27%) used tabs to begin with then had two windows side by side
- ARCGIS ONLINE – GENERAL GLITCHES: All 11 participants (100%) experienced some sort of glitch or issue with ArcGIS Online
- ARCGIS ONLINE – TOUR: 3 participants (27%) had selected the "Take a Map Tour" option that was initially available to learn about the map functionality, though they did not follow it all the way through
- ARCGIS ONLINE – FAMILIAR LOCATION: 5 participants (45%), when they first loaded the map, navigated to somewhere that may have been familiar to them (e.g. home, work, etc.)
- ARCGIS ONLINE – RELOAD: 10 participants (91%) reloaded the map at some point, on purpose or accidentally, and lost unsaved changes as a result
- ARCGIS ONLINE – CHANGING SYMBOLOGY: 1 participant (9%) clicked the symbol under the layer to try and change its symbology
- ARCGIS ONLINE – WEB MAP vs. WEB APP: 2 participants (18%) had difficulty understanding the difference between the web map and web app in Contents, especially as they both had the same name
- ARCGIS ONLINE – GETTING BACK TO INTERFACE: 4 participants (36%) had difficulty getting from the Web App back to the main ArcGIS Online interface and, once they did, then had to sign back in, as the session variable was not saved in the browser
- SEARCH FOR LAYER: 1 participant (9%) had difficulty when searching for layers in ArcGIS Online, as they had not used the exact layer name or the box was selected to only show layers within the current map extent
- ADD FROM FILE (SHP): 4 participants (36%) were confused about the zipped shapefile, whether to unzip it or not and, if so, which file to add

- ADD FROM WEB (KML) – GENERAL UNDERSTANDING: 5 participants (45%) had difficulty with understanding the KML was a remote resource that simply required the correct URL, rather than downloading the physical file, to add it to the map
- ADD FROM WEB (KML) – SELECT FILE: 1 participant (9%) did not change the drop down when adding the KML layer to be for a KML file, though the layer was still added to the map correctly
- ADD FROM WEB (KML) – DISPLAY GLITCH: 4 participants (36%) experienced an issue with the KML, which referenced an image, not displaying in the correct location in the Story Map
- ADD MAP NOTES LAYER – FROM SEARCH RESULT: 2 participants (18%) added the map note layer from the option given in a search result pop up rather than from the add layer menu
- ADD MAP NOTES LAYER – DIFFICULTIES: 11 participants (100%) experienced issues with add map notes, either with getting in or out of edit mode, confusion on adding an element to the map or due to the “https://” automatically added to the image URL or image link fields
- STORY MAPS – TABBED LAYOUT: 5 participants (45%) had difficulty understanding that the tabbed layout was part of the Story Map series template
- STORY MAPS – FROM WEBSITE: 8 participants (73%) created the Story Map from the Story Maps website which was discovered as the result of a search, rather than through the ArcGIS Online interface they had been working in
- STORY MAPS – IMAGE AS TAB: 9 participants (82%) had initially added the image that was to be added in the description for the Story Map as a separate tab
- STORY MAPS – EXTRA TABS: 2 participants (18%) had difficulty deleting extra tabs they had created in the Story Map
- INTERNET SEARCH – WRONG RESOURCE: 3 participants (27%) had searched for an answer to an issue they had experienced in the GIS, but had instead reviewed resources for ArcGIS Pro or ArcGIS for Desktop instead of ArcGIS Online
- WORKSHOP QUESTIONS: 7 participants (64%) asked the researcher or volunteer a question; these were on the image in the Story Map description, creating a web app, where to save files, symbology, glitches, login issues and general GIS guidance

A.6.6 Task Completion Times – Comparing Formal and Informal Workshops

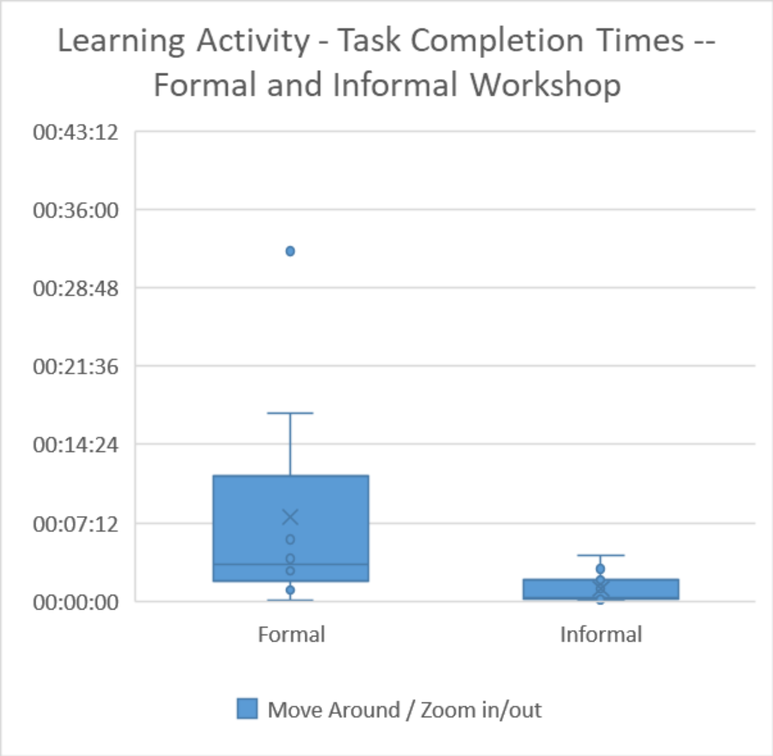

Figure A.6.1 Learning Activity – Task Completion Times – Formal and Informal Workshops: Move Around / Zoom in/out

The completion for the task Move Around / Zoom in/out in the Learning Activity, as shown in Figure A.6.1, shows that for the formal workshop, the median completion time was 00h:03m:26s and the inter-quartile range was 00h:01m:53s – 00h:11m:29s (a difference of 00h:09m:36s). In the informal workshop, the median completion time was 00h:00m:19s and the inter-quartile range was 00h:00m:09s – 00h:01m:56s (a difference of 00h:01m:47s). Comparing the formal and informal workshop results, the formal workshop median was 00h:03m:07s later than the informal workshop and the inter-quartile range of the formal workshop was 00h:07m:49s longer than the informal workshop.

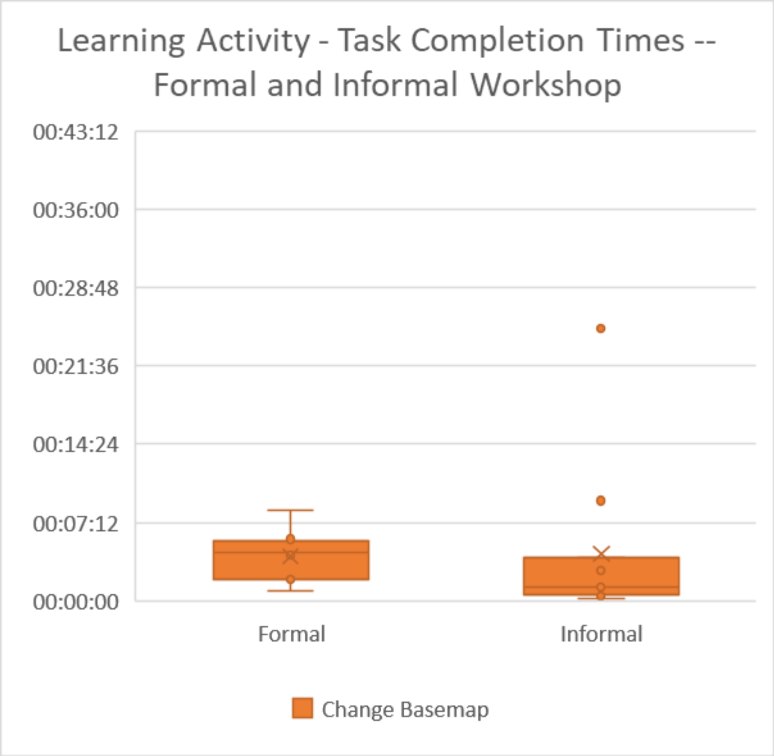

Figure A.6.2 Learning Activity – Task Completion Times – Formal and Informal Workshops: Change Basemap

The completion for the task Change Basemap in the Learning Activity, as shown in Figure A.6.2 shows that for the formal workshop, the median completion time was 00h:04m:27s and the inter-quartile range was 00h:02m:01s – 00h:05m:29s (a difference of 00h:03m:28s). In the informal workshop, the median completion time was 00h:01m:15s and the inter-quartile range was 00h:00m:36s – 00h:04m:00s (a difference of 00h:03m:24s). Comparing the formal and informal workshop results, the formal workshop median was 00h:03m:12s later than the informal workshop and the inter-quartile range of the formal workshop was 00h:00m:04s longer than the informal workshop.

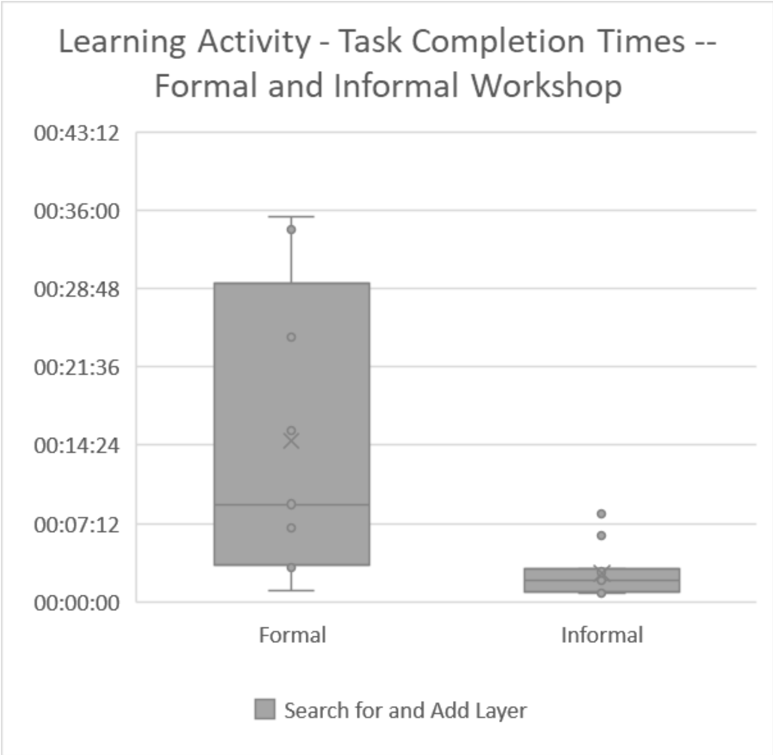

Figure A.6.3 Learning Activity – Task Completion Times – Formal and Informal Workshops: Search for and Add Layer

The completion for the task Search for and Add Layer in the Learning Activity, as shown in Figure A.6.3, shows that for the formal workshop, the median completion time was 00h:08m:58s and the inter-quartile range was 00h:03m:25s – 00h:29m:17s (a difference of 00h:25m:52s). In the informal workshop, the median completion time was 00h:01m:58s and the inter-quartile range was 00h:00m:57s – 00h:02m:58s (a difference of 00h:02m:01s). Comparing the formal and informal workshop results, the formal workshop median was 00h:07m:00s later than the informal workshop and the inter-quartile range of the formal workshop was 00h:23m:51s longer than the informal workshop.

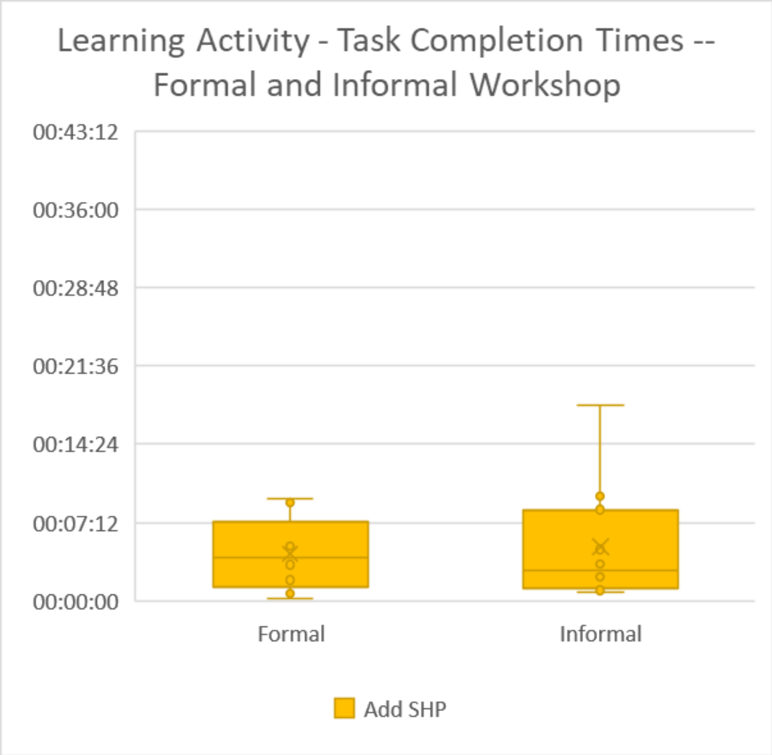

Figure A.6.4 Learning Activity – Task Completion Times – Formal and Informal Workshops: Add SHP

The completion for the task Add SHP in the Learning Activity, as shown in Figure A.6.4, shows that for the formal workshop, the median completion time was 00h:04m:00s and the inter-quartile range was 00h:01m:17s – 00h:07m:17s (a difference of 00h:06m:00s). In the informal workshop, the median completion time was 00h:02m:49s and the inter-quartile range was 00h:01m:07s – 00h:08m:22s (a difference of 00h:07m:15s). Comparing the formal and informal workshop results, the formal workshop median was 00h:01m:11s later than the informal workshop and the inter-quartile range of the formal workshop was 00h:01m:15s shorter than the informal workshop.

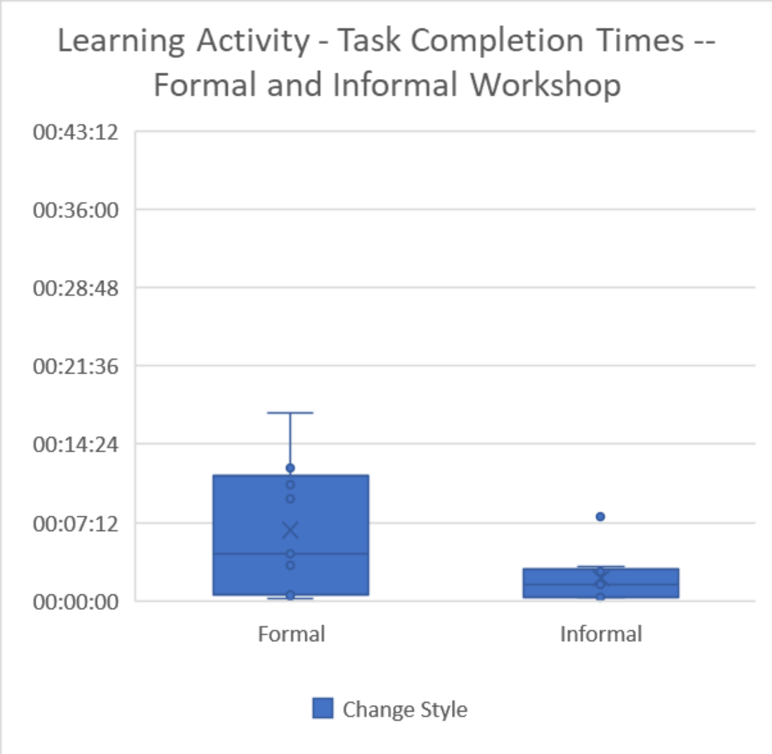

Figure A.6.5 Learning Activity – Task Completion Times – Formal and Informal Workshops: Change Style

The completion for the task Change Style in the Learning Activity, as shown in Figure A.6.5, shows that for the formal workshop, the median completion time was 00h:04m:19s and the inter-quartile range was 00h:00m:31s – 00h:11m:26s (a difference of 00h:10m:55s). In the informal workshop, the median completion time was 00h:01m:32s and the inter-quartile range was 00h:00m:19s – 00h:02m:56s (a difference of 00h:02m:37s). Comparing the formal and informal workshop results, the formal workshop median was 00h:02m:47s later than the informal workshop and the inter-quartile range of the formal workshop was 00h:08m:18s longer than the informal workshop.

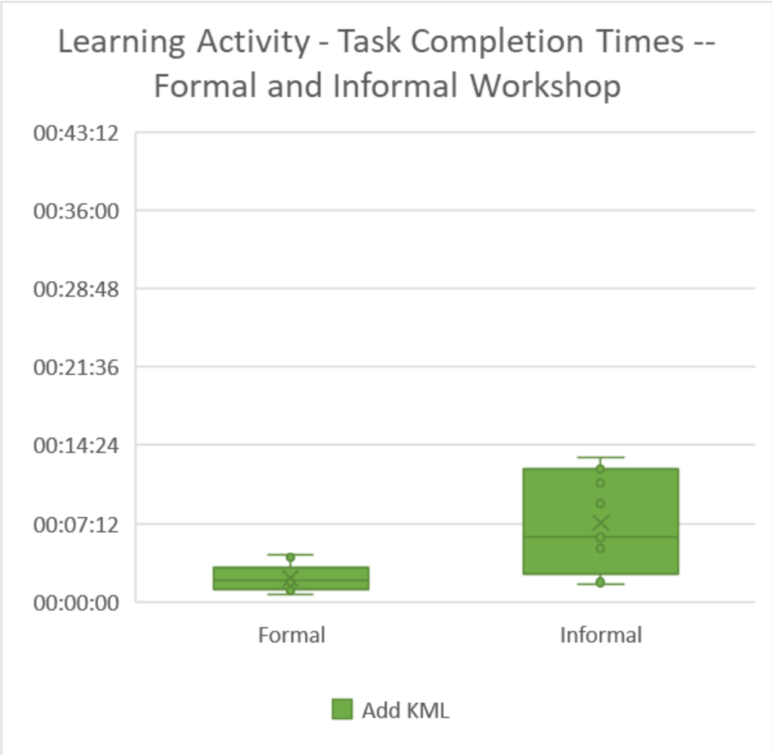

Figure A.6.6 Learning Activity – Task Completion Times – Formal and Informal Workshops: Add KML

The completion for the task Add KML in the Learning Activity, as shown in Figure A.6.6, shows that for the formal workshop, the median completion time was 00h:01m:59s and the inter-quartile range was 00h:01m:06s – 00h:03m:07s (a difference of 00h:02m:01s). In the informal workshop, the median completion time was 00h:05m:55s and the inter-quartile range was 00h:02m:31s – 00h:12m:11s (a difference of 00h:09m:40s). Comparing the formal and informal workshop results, the formal workshop median was 00h:03m:56s earlier than the informal workshop and the inter-quartile range of the formal workshop was 00h:07m:39s shorter than the informal workshop.

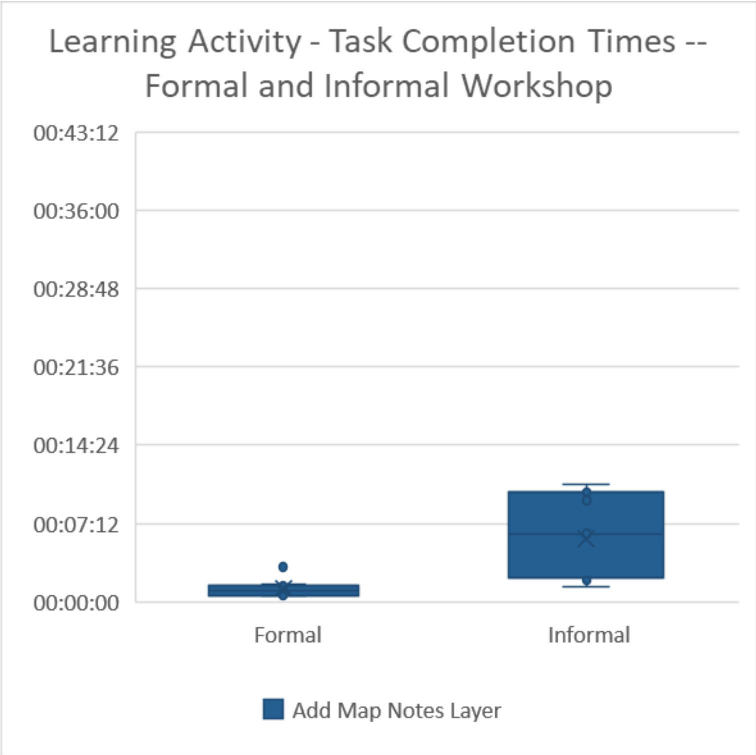

Figure A.6.7 Learning Activity – Task Completion Times – Formal and Informal Workshops: Add Map Notes Layer

The completion for the task Add Map Notes Layer in the Learning Activity, as shown in Figure A.6.7, shows that for the formal workshop, the median completion time was 00h:01m:02s and the inter-quartile range was 00h:00m:36s – 00h:01m:32s (a difference of 00h:00m:56s). In the informal workshop, the median completion time was 00h:06m:15s and the inter-quartile range was 00h:02m:11s – 00h:10m:02s (a difference of 00h:07m:51s). Comparing the formal and informal workshop results, the formal workshop median was 00h:05m:13s earlier than the informal workshop and the inter-quartile range of the formal workshop was 00h:06m:55s shorter than the informal workshop.

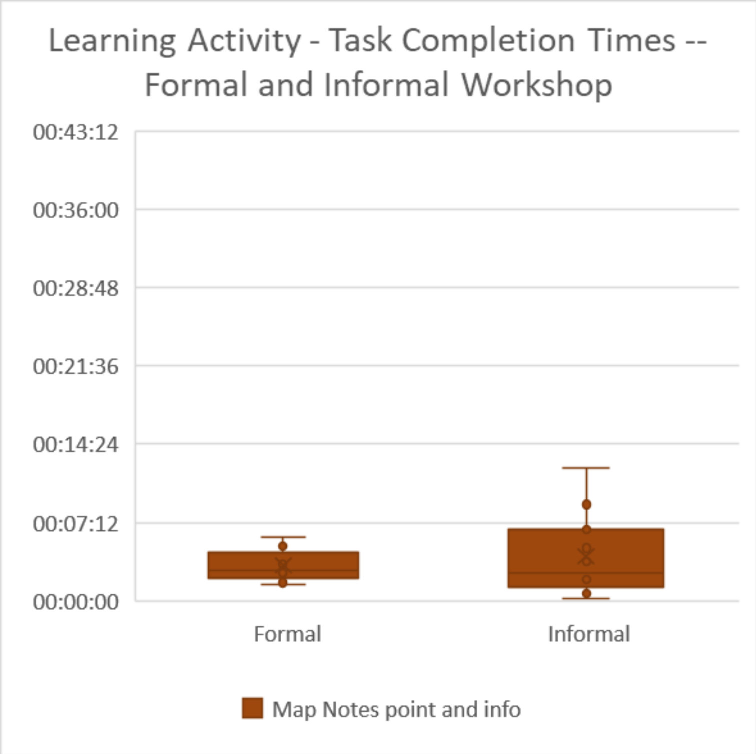

Figure A.6.8 Learning Activity – Task Completion Times – Formal and Informal Workshops: Map Notes point and info

The completion for the task Map Notes point and info in the Learning Activity, as shown in Figure A.6.8, shows that for the formal workshop, the median completion time was 00h:02m:44s and the inter-quartile range was 00h:02m:08s – 00h:04m:26s (a difference of 00h:02m:18s). In the informal workshop, the median completion time was 00h:02m:33s and the inter-quartile range was 00h:01m:15s – 00h:06m:35s (a difference of 00h:05m:20s). Comparing the formal and informal workshop results, the formal workshop median was 00h:00m:11s later than the informal workshop and the inter-quartile range of the formal workshop was 00h:03m:02s shorter than the informal workshop.

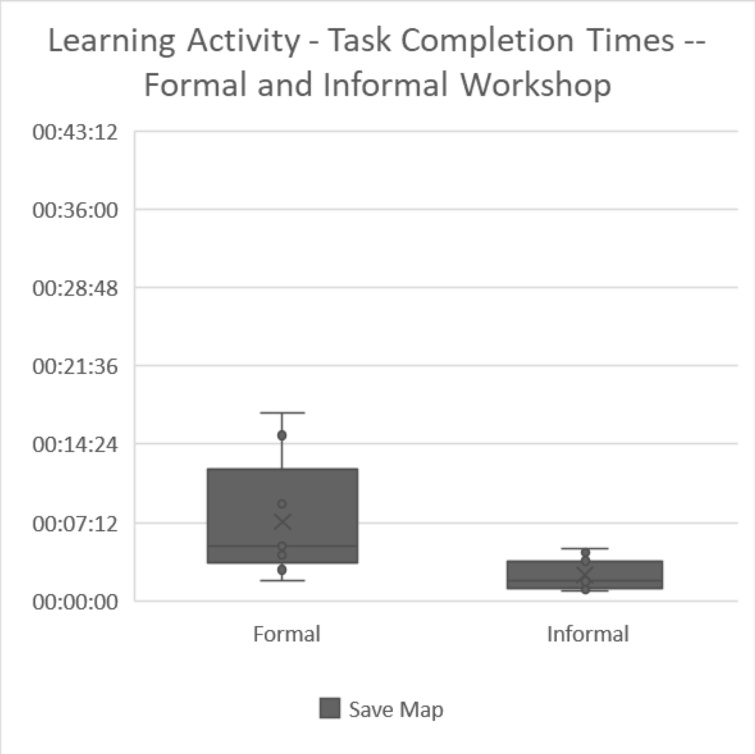

Figure A.6.9 Learning Activity – Task Completion Times – Formal and Informal Workshops: Save Map

The completion for the task Save Map in the Learning Activity, as shown in Figure A.6.9, shows that for the formal workshop, the median completion time was 00h:05m:03s and the inter-quartile range was 00h:03m:30s – 00h:12m:04s (a difference of 00h:08m:34s). In the informal workshop, the median completion time was 00h:01m:50s and the inter-quartile range was 00h:01m:08s – 00h:03m:40s (a difference of 00h:02m:32s). Comparing the formal and informal workshop results, the formal workshop median was 00h:03m:13s later than the informal workshop and the inter-quartile range of the formal workshop was 00h:06m:02s longer than the informal workshop.

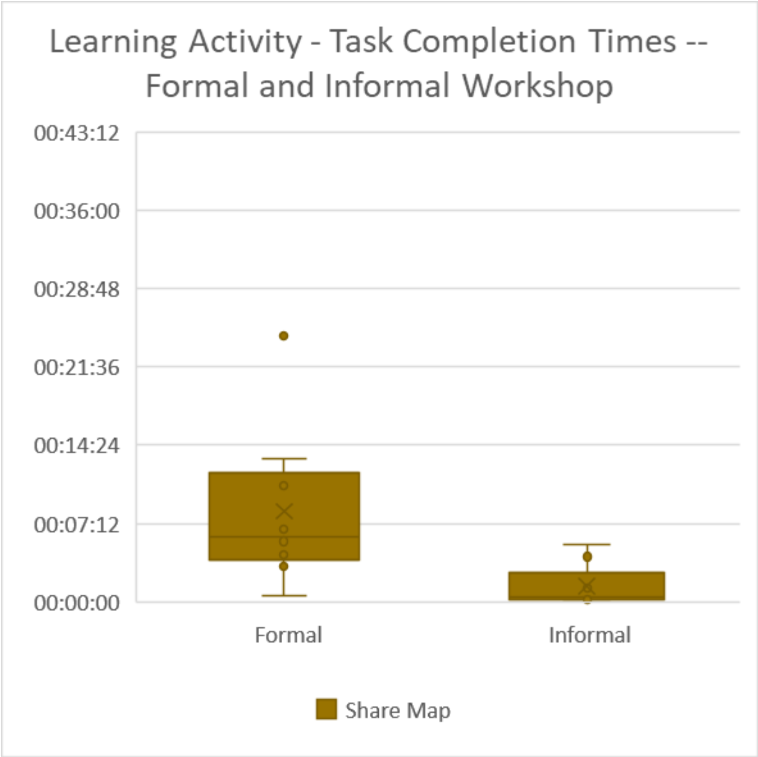

Figure A.6.10 Learning Activity – Task Completion Times – Formal and Informal Workshops: Share Map

The completion for the task Share Map in the Learning Activity, as shown in Figure A.6.10, shows that for the formal workshop, the median completion time was 00h:06m:00s and the inter-quartile range was 00h:03m:48s – 00h:11m:54s (a difference of 00h:08m:06s). In the informal workshop, the median completion time was 00h:00m:28s and the inter-quartile range was 00h:00m:14s – 00h:02m:44s (a difference of 00h:02m:30s). Comparing the formal and informal workshop results, the formal workshop median was 00h:05m:32s later than the informal workshop and the inter-quartile range of the formal workshop was 00h:02m:34s longer than the informal workshop.

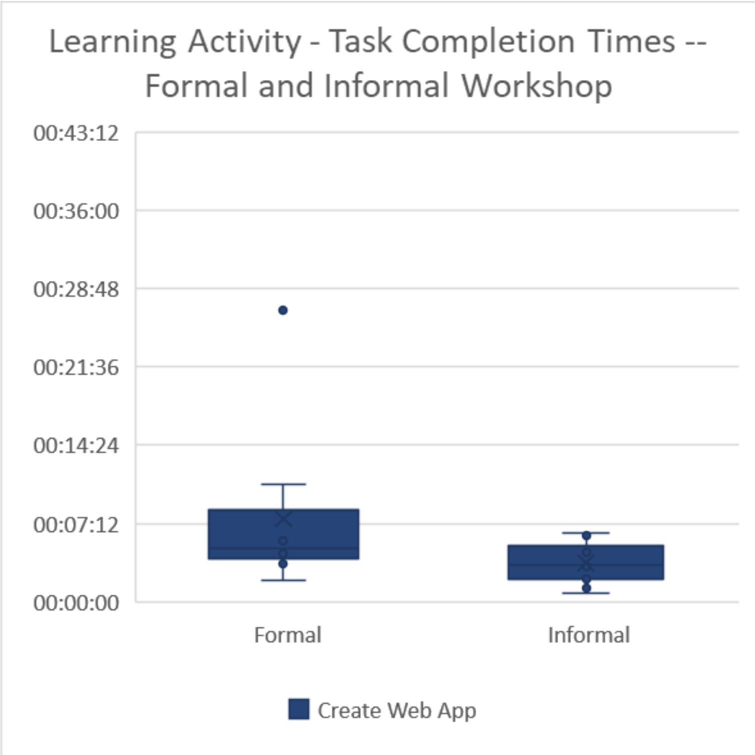

Figure A.6.11 Learning Activity – Task Completion Times – Formal and Informal Workshops: Create Web App

The completion for the task Create Web App in the Learning Activity, as shown in Figure A.6.11, shows that for the formal workshop, the median completion time was 00h:04m:57s and the inter-quartile range was 00h:04m:00s – 00h:08m:29s (a difference of 00h:04m:29s). In the informal workshop, the median completion time was 00h:03m:23s and the inter-quartile range was 00h:02m:05s – 00h:05m:12s (a difference of 00h:03m:07s). Comparing the formal and informal workshop results, the formal workshop median was 00h:01m:34s later than the informal workshop and the inter-quartile range of the formal workshop was 00h:01m:22s longer than the informal workshop.

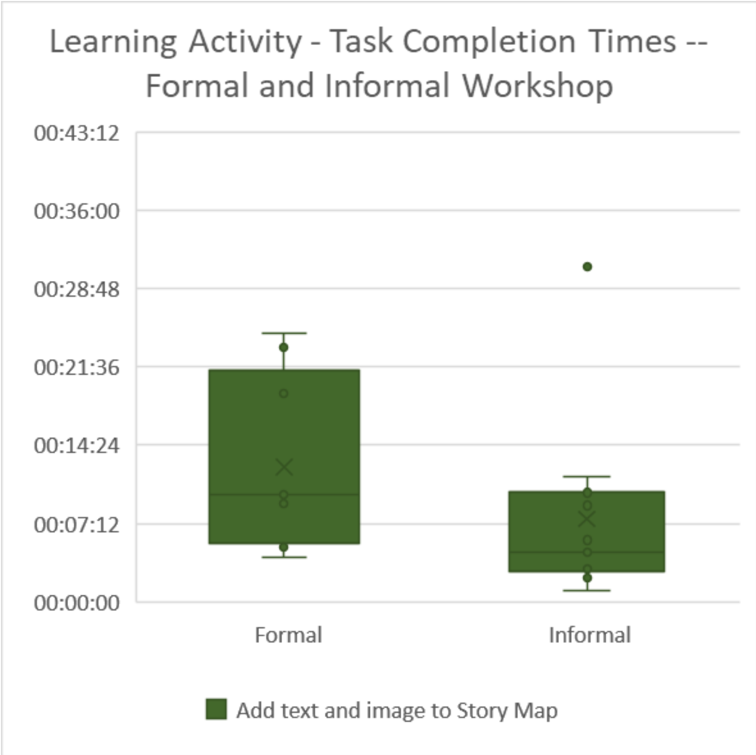

Figure A.6.12 Learning Activity – Task Completion Times – Formal and Informal Workshops: Add text and image to Story Map

The completion for the task Add text and image to Story Map in the Learning Activity, as shown in Figure A.6.12, shows that for the formal workshop, the median completion time was 00h:09m:51s and the inter-quartile range was 00h:05m:23s – 00h:21m:18s (a difference of 00h:15m:55s). In the informal workshop, the median completion time was 00h:04m:31s and the inter-quartile range was 00h:02m:48s – 00h:10m:02s (a difference of 00h:07m:14s). Comparing the formal and informal workshop results, the formal workshop median was 00h:05m:20s later than the informal workshop and the inter-quartile range of the formal workshop was 00h:08m:41s longer than the informal workshop.

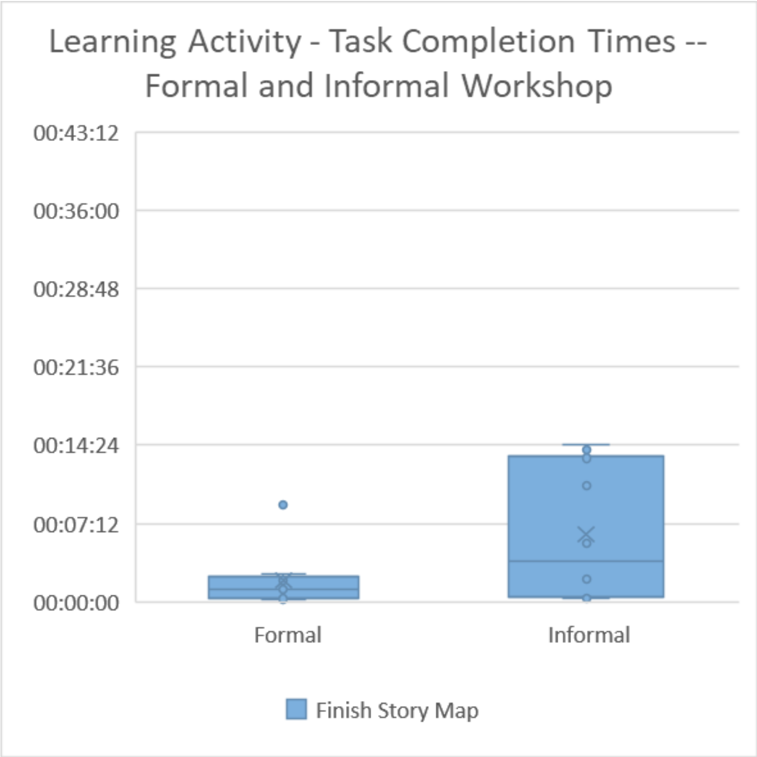

Figure A.6.13 Learning Activity – Task Completion Times – Formal and Informal Workshops: Finish Story Map

The completion for the task Finish Story Map in the Learning Activity, as shown in Figure A.6.13, shows that for the formal workshop, the median completion time was 00h:01m:09s and the inter-quartile range was 00h:00m:17s – 00h:02m:16s (a difference of 00h:01m:59s). In the informal workshop, the median completion time was 00h:03m:45s and the inter-quartile range was 00h:00m:28s – 00h:13m:24s (a difference of 00h:12m:56s). Comparing the formal and informal workshop results, the formal workshop median was 00h:02m:36s earlier than the informal workshop and the inter-quartile range of the formal workshop was 00h:10m:57s shorter than the informal workshop.

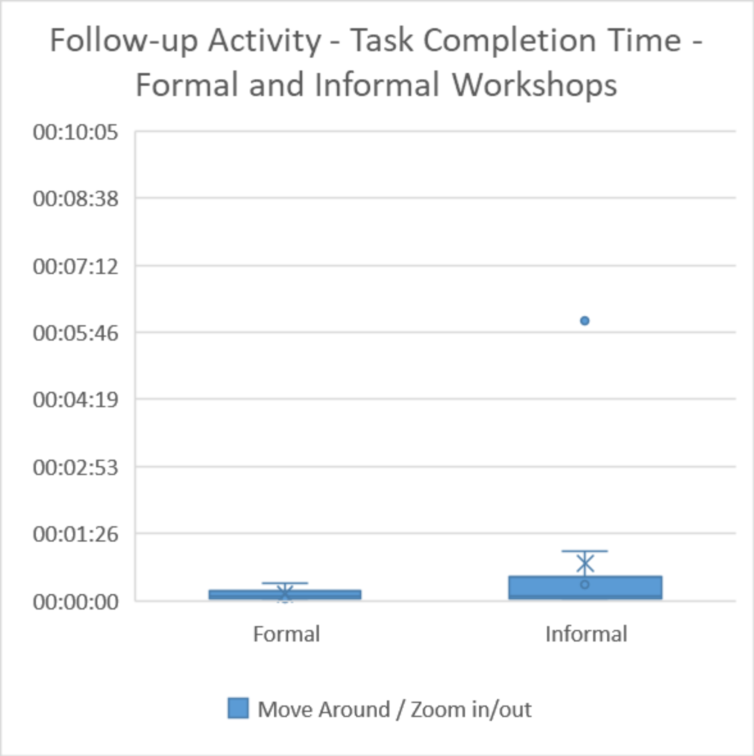

Figure A.6.14 Follow-up Activity – Task Completion Times – Formal and Informal Workshops: Move Around / Zoom in/out

The completion for the task Move Around / Zoom in/out in the Follow-up Activity, as shown in Figure A.6.14, shows that for the formal workshop, the median completion time was 00h:00m:07s and the inter-quartile range was 00h:00m:03s – 00h:00m:12s (a difference of 00h:00m:09s). In the informal workshop, the median completion time was 00h:00m:06s and the inter-quartile range was 00h:00m:03s – 00h:00m:31s (a difference of 00h:00m:28s). Comparing the formal and informal workshop results, the formal workshop median was 00h:00m:01s later than the informal workshop and the inter-quartile range of the formal workshop was 00h:00m:19s shorter than the informal workshop.

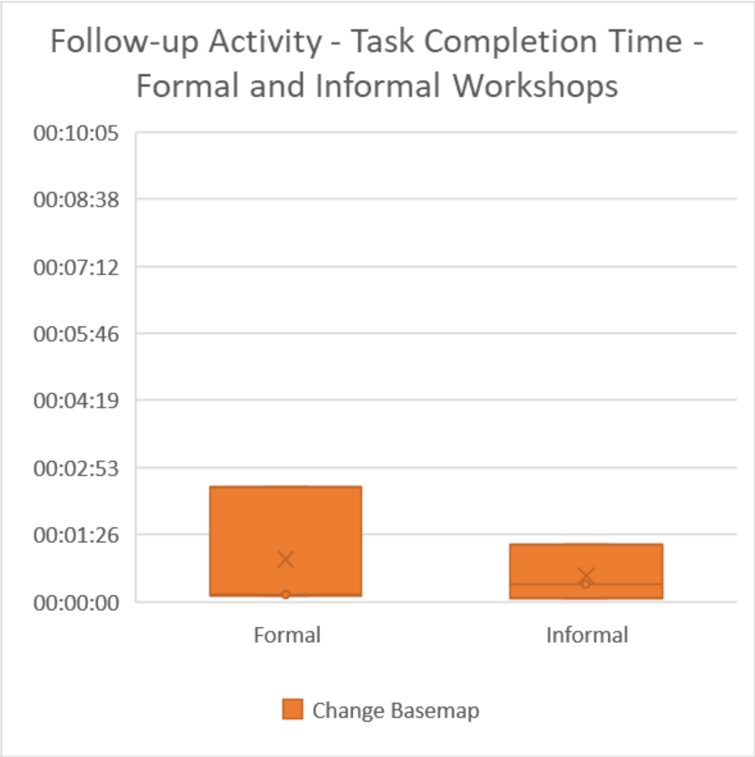

Figure A.6.15 Follow-up Activity – Task Completion Times – Formal and Informal Workshops: Change Basemap

The completion for the task Change Basemap in the Follow-up Activity, as shown in Figure A.6.15, shows that for the formal workshop, the median completion time was 00h:00m:09s and the inter-quartile range was 00h:00m:08s – 00h:02m:27s (a difference of 00h:02m:19s). In the informal workshop, the median completion time was 00h:00m:22s and the inter-quartile range was 00h:00m:05s – 00h:01m:13s (a difference of 00h:01m:08s). Comparing the formal and informal workshop results, the formal workshop median was 00h:00m:13s earlier than the informal workshop and the inter-quartile range of the formal workshop was 00h:01m:11s longer than the informal workshop.

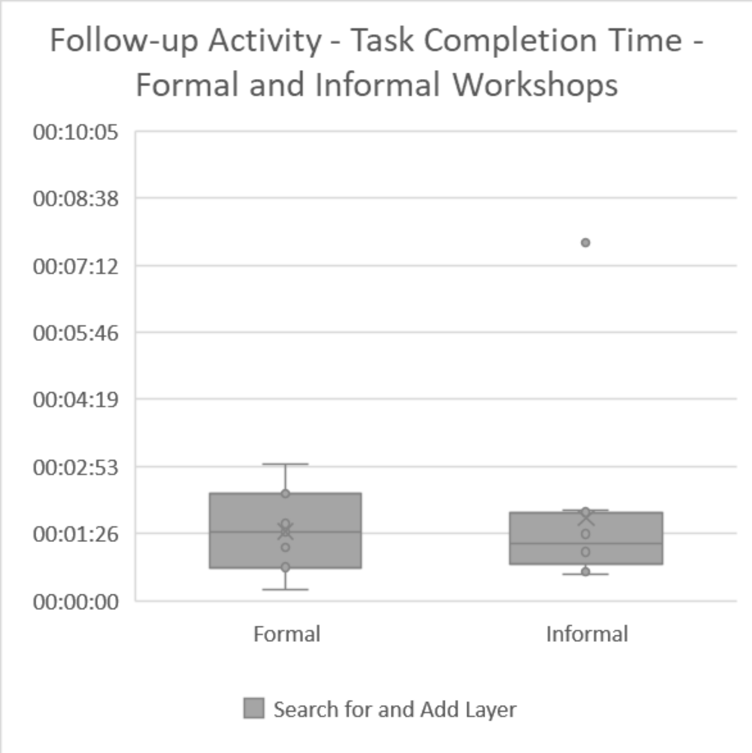

Figure A.6.16 Follow-up Activity – Task Completion Times – Formal and Informal Workshops: Search for and Add Layer

The completion for the task Search for and Add Layer in the Follow-up Activity, as shown in Figure A.6.16, shows that for the formal workshop, the median completion time was 00h:01m:28s and the inter-quartile range was 00h:00m:43s – 00h:02m:18s (a difference of 00h:01m:35s). In the informal workshop, the median completion time was 00h:01m:13s and the inter-quartile range was 00h:00m:47s – 00h:01m:54s (a difference of 00h:00m:47s). Comparing the formal and informal workshop results, the formal workshop median was 00h:00m:15s later than the informal workshop and the inter-quartile range of the formal workshop was 00h:00m:48s longer than the informal workshop.

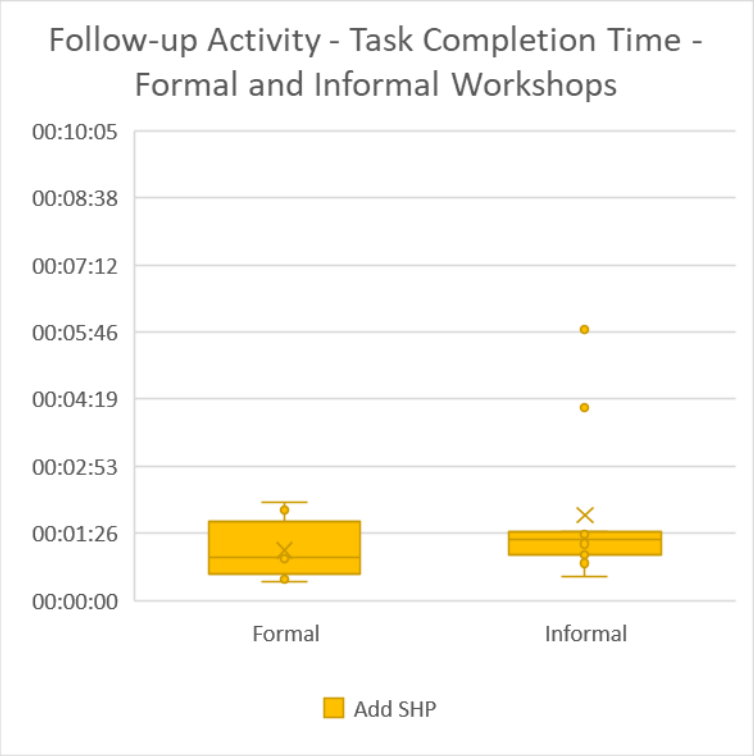

Figure A.6.17 Follow-up Activity – Task Completion Times – Formal and Informal Workshops: Add SHP

The completion for the task Add SHP in the Follow-up Activity, as shown in Figure A.6.17, shows that for the formal workshop, the median completion time was 00h:00m:55s and the inter-quartile range was 00h:00m:34s – 00h:01m:41s (a difference of 00h:01m:07s). In the informal workshop, the median completion time was 00h:01m:19s and the inter-quartile range was 00h:00m:59s – 00h:01m:29s (a difference of 00h:00m:30s). Comparing the formal and informal workshop results, the formal workshop median was 00h:00m:24s earlier than the informal workshop and the inter-quartile range of the formal workshop was 00h:00m:37s longer than the informal workshop.

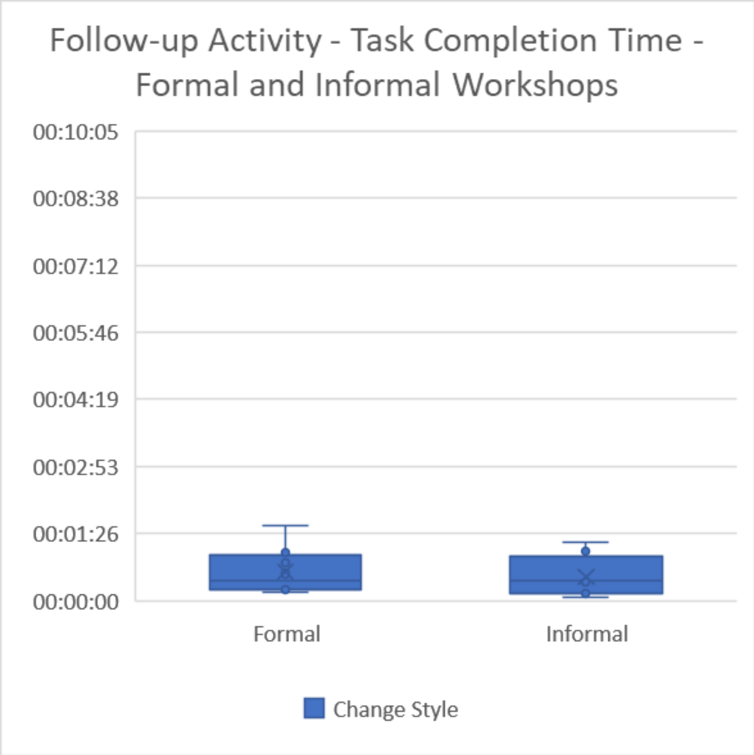

Figure A.6.18 Follow-up Activity – Task Completion Times – Formal and Informal Workshops: Change Style

The completion for the task Change Style in the Follow-up Activity, as shown in Figure A.6.18, shows that for the formal workshop, the median completion time was 00h:00m:26s and the inter-quartile range was 00h:00m:14s – 00h:00m:59s (a difference of 00h:00m:45s). In the informal workshop, the median completion time was 00h:00m:26s and the inter-quartile range was 00h:00m:09s – 00h:00m:56s (a difference of 00h:00m:47s). Comparing the formal and informal workshop results, the formal workshop medians were the same and the inter-quartile range of the formal workshop was 00h:00m:02s shorter than the informal workshop.

Figure A.6.19 Follow-up Activity – Task Completion Times – Formal and Informal Workshops: Add KML

The completion for the task Add KML in the Follow-up Activity, as shown in Figure A.6.19, shows that for the formal workshop, the median completion time was 00h:01m:16s and the inter-quartile range was 00h:00m:57s – 00h:02m:31s (a difference of 00h:01m:34s). In the informal workshop, the median completion time was 00h:01m:24s and the inter-quartile range was 00h:01m:12s – 00h:02m:25s (a difference of 00h:01m:13s). Comparing the formal and informal workshop results, the formal workshop median was 00h:00m:08s earlier than the informal workshop and the inter-quartile range of the formal workshop was 00h:00m:19s longer than the informal workshop.

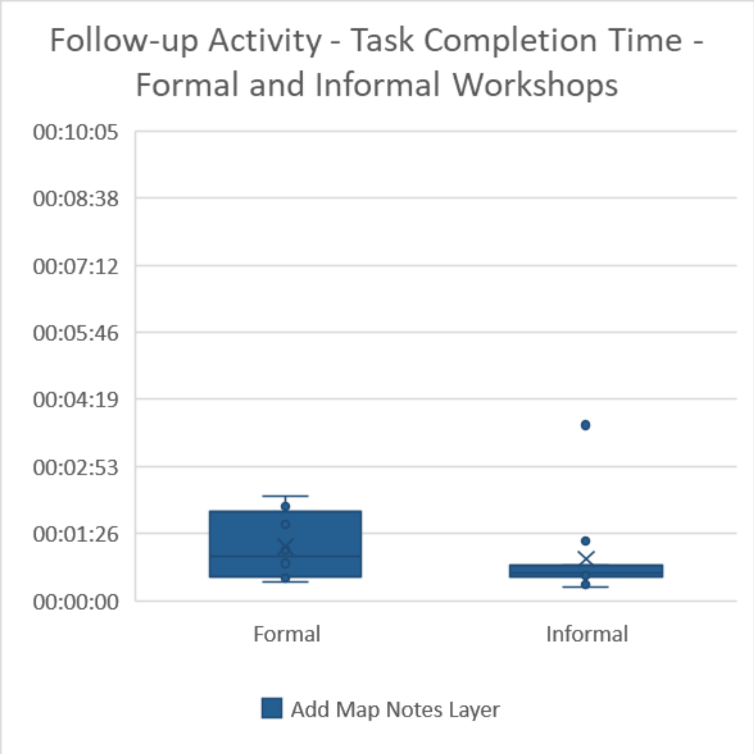

Figure A.6.20 Follow-up Activity – Task Completion Times – Formal and Informal Workshops: Add Map Notes Layer

The completion for the task Add Map Notes Layer in the Follow-up Activity, as shown in Figure A.6.20, shows that for the formal workshop, the median completion time was 00h:00m:57s and the inter-quartile range was 00h:00m:30s – 00h:01m:55s (a difference of 00h:01m:25s). In the informal workshop, the median completion time was 00h:00m:35s and the inter-quartile range was 00h:00m:31s – 00h:00m:46s (a difference of 00h:00m:15s). Comparing the formal and informal workshop results, the formal workshop median was 00h:00m:22s later than the informal workshop and the inter-quartile range of the formal workshop was 00h:01m:10s longer than the informal workshop.

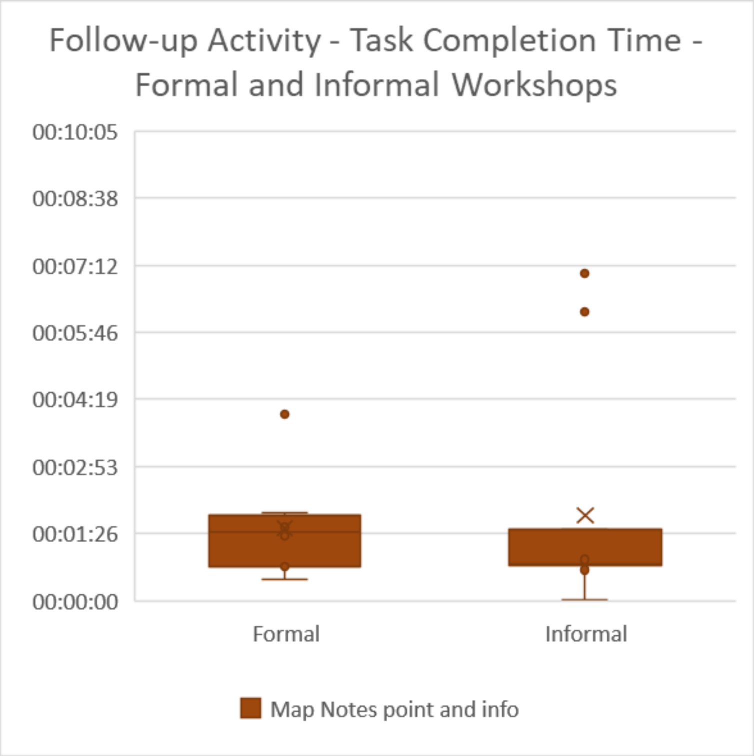

Figure A.6.21 Follow-up Activity – Task Completion Times – Formal and Informal Workshops: Map Notes point and info

The completion for the task Map Notes point and info in the Follow-up Activity, as shown in Figure A.6.21, shows that for the formal workshop, the median completion time was 00h:01m:29s and the inter-quartile range was 00h:00m:44s – 00h:01m:49s (a difference of 00h:01m:05s). In the informal workshop, the median completion time was 00h:00m:47s and the inter-quartile range was 00h:00m:46s – 00h:01m:32s (a difference of 00h:00m:46s). Comparing the formal and informal workshop results, the formal workshop median was 00h:00m:42s later than the informal workshop and the inter-quartile range of the formal workshop was 00h:00m:19s longer than the informal workshop.

Figure A.6.22 Follow-up Activity – Task Completion Times – Formal and Informal Workshops: Save Map

The completion for the task Save Map in the Follow-up Activity, as shown in Figure A.6.22, shows that for the formal workshop, the median completion time was 00h:00m:55s and the inter-quartile range was 00h:00m:43s – 00h:01m:04s (a difference of 00h:00m:21s). In the informal workshop, the median completion time was 00h:00m:59s and the inter-quartile range was 00h:00m:48s – 00h:01m:51s (a difference of 00h:01m:03s). Comparing the formal and informal workshop results, the formal workshop median was 00h:00m:04s earlier than the informal workshop and the inter-quartile range of the formal workshop was 00h:00m:42s shorter than the informal workshop.

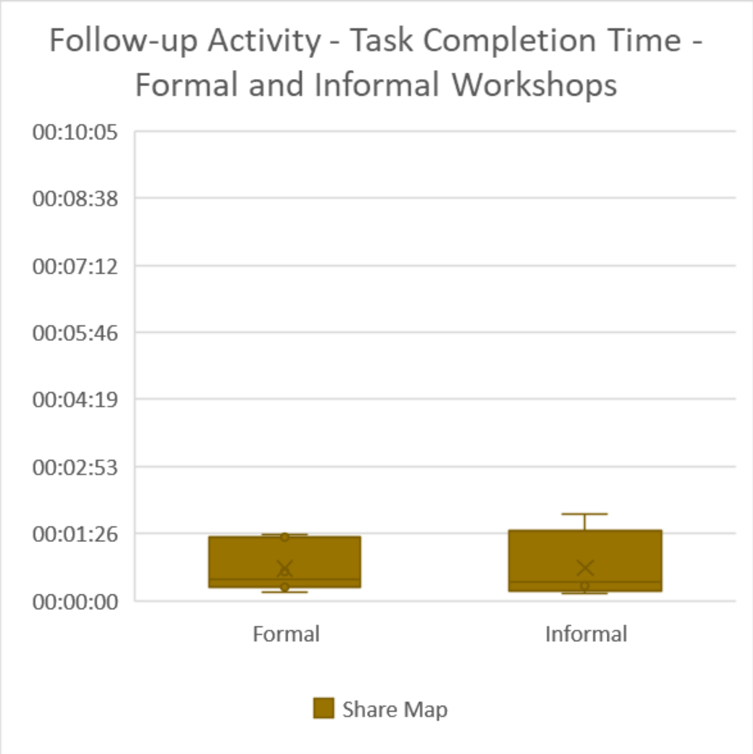

Figure A.6.23 Follow-up Activity – Task Completion Times – Formal and Informal Workshops: Share Map

The completion for the task Share Map in the Follow-up Activity, as shown in Figure A.6.23, shows that for the formal workshop, the median completion time was 00h:00m:28s and the inter-quartile range was 00h:00m:18s – 00h:01m:22s (a difference of 00h:01m:04s). In the informal workshop, the median completion time was 00h:00m:23s and the inter-quartile range was 00h:00m:12s – 00h:01m:30s (a difference of 00h:01m:18s). Comparing the formal and informal workshop results, the formal workshop median was 00h:00m:05s later than the informal workshop and the inter-quartile range of the formal workshop was 00h:00m:14s shorter than the informal workshop.

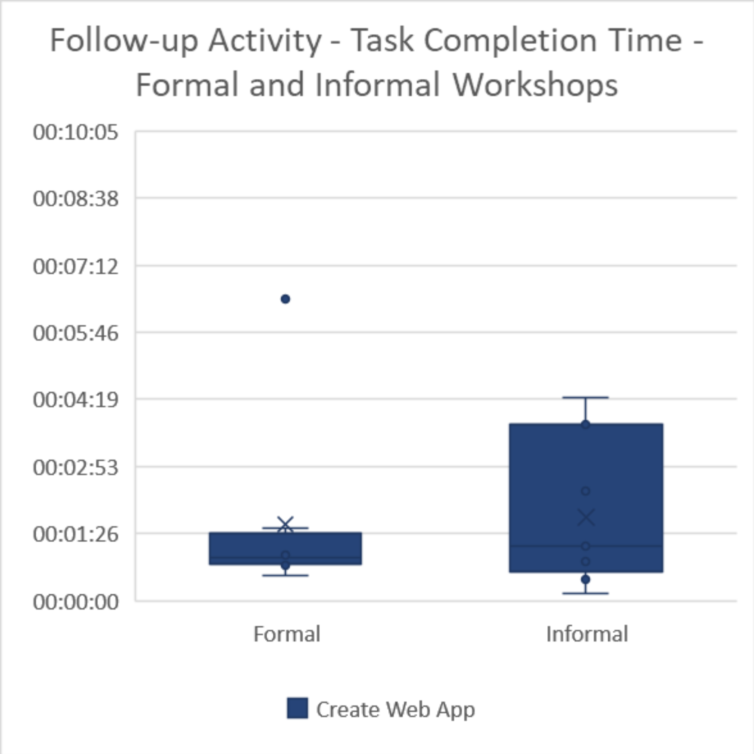

Figure A.6.24 Follow-up Activity – Task Completion Times – Formal and Informal Workshops: Create Web App

The completion for the task Create Web App in the Follow-up Activity, as shown in Figure A.6.24, shows that for the formal workshop, the median completion time was 00h:00m:55s and the inter-quartile range was 00h:00m:47s – 00h:01m:27s (a difference of 00h:00m:40s). In the informal workshop, the median completion time was 00h:01m:10s and the inter-quartile range was 00h:00m:38s – 00h:03m:47s (a difference of 00h:03m:09s). Comparing the formal and informal workshop results, the formal workshop median was 00h:00m:15s earlier than the informal workshop and the inter-quartile range of the formal workshop was 00h:02m:29s shorter than the informal workshop.

Figure A.6.25 Follow-up Activity – Task Completion Times – Formal and Informal Workshops: Add text and image to Story Map

The completion for the task Add text and image to Story Map in the Follow-up Activity, as shown in Figure A.6.25, shows that for the formal workshop, the median completion time was 00h:01m:54s and the inter-quartile range was 00h:01m:02s – 00h:03m:15s (a difference of 00h:02m:13s). In the informal workshop, the median completion time was 00h:01m:43s and the inter-quartile range was 00h:01m:16s – 00h:02m:11s (a difference of 00h:00m:55s). Comparing the formal and informal workshop results, the formal workshop median was 00h:00m:11s later than the informal workshop and the inter-quartile range of the formal workshop was 00h:01m:18s longer than the informal workshop.

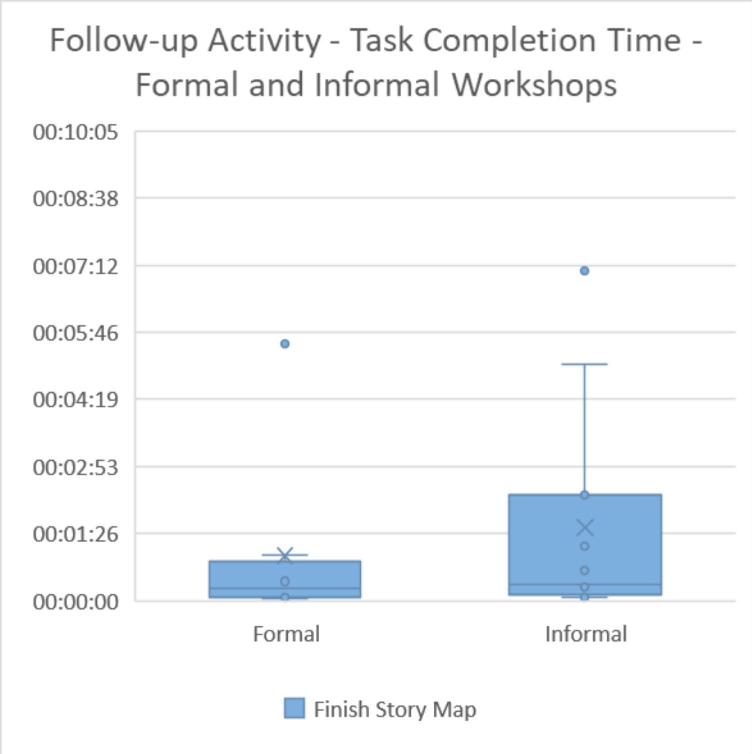

Figure A.6.26 Follow-up Activity – Task Completion Times – Formal and Informal Workshops: Finish Story Map

The completion for the task Finish Story Map in the Follow-up Activity, as shown in Figure A.6.26, shows that for the formal workshop, the median completion time was 00h:00m:16s and the inter-quartile range was 00h:00m:05s – 00h:00m:51s (a difference of 00h:00m:46s). In the informal workshop, the median completion time was 00h:00m:21s and the inter-quartile range was 00h:00m:07s – 00h:02m:16s (a difference of 00h:02m:09s). Comparing the formal and informal workshop results, the formal workshop median was 00h:00m:05s earlier than the informal workshop and the inter-quartile range of the formal workshop was 00h:01m:23s shorter than the informal workshop.