What is GIScience – What is GIScience NOT?

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Abstract

Despite the fact that the field of GIScience has now been around for a little over two decades, there is still little consensus as to the exact contents and boundaries of the field. Many authors have dedicated several publications concerned with defining the field, yet little consensus has been reached. In this paper, a historical overview of GIScience is presented and its context within the framework of Geography, GIS and science in general is explored. Furthermore, the competing views of various key players in the field of GIScience are structured in an attempt to subsequently derive a possible answer to the proposed research question, namely 'what is GIScience – what is GIScience not'.

1. Introduction

Over the past three decades, a myriad of publications have emerged regarding the field of GIScience, many of which were primarily concerned with defining the term itself, as well as justifying GIScience to the geo-community. Goodchild (2009: 527) states that *"GIScience is variously defined as the science behind the systems; the set of fundamental questions raised by GIS; the research field that will define the next generation of GIS; the body of knowledge that GIS implements; and the use of GIS as a tool for scientific research. As a science of geographic information it represents a subset of information science; while its relationship to the discipline of geography, and to other disciplines that deal with the surface and nearsurface of the Earth, is a subject of continuing debate"*. The vast number of definitions of GIScience, contributed to the body of knowledge by various key players, makes it difficult to delimit the boundaries of the field, as well as determine its exact research contents. When Michael Goodchild first coined the term 'GIScience' in his paper entitled "Geographical Information Science" (1992), he defined it as *"the science behind the systems, concerned with the set of fundamental questions raised by GIS and allied technologies"* (Goodchild 1992: 32), however, in the years that followed several competing definitions emerged, all of which seem to boil down to the same essential notion *"that behind the technologies lie a series of fundamental issues of profound importance. These are the issues raised by the use of the technologies, and captured in what is often termed critical spatial thinking. They include scale, accuracy and uncertainty, ontology, and the representation of complex geographic phenomena"* (Goodchild 2009: 1040). Furthermore, Agarwal (2005: 502) state that *"since GIScience is itself an evolving discipline, the boundaries of, and within, this discipline are not yet well defined. There is a distinct lack of an integrated scientific framework of commonly accepted terms and methods that are needed to establish GIS as a science"*. The University

Consortium for Geographic Information Science (UCGIS) provided yet another definition of GIScience, stating that *""The University Consortium for Geographic Information Science is dedicated to the development and use of theories, methods, technology, and data for understanding geographic processes, relationships, and patterns. The transformation of geographic data into useful information is central to geographic information science"* (UCGIS, 2002). A full, comprehensive definition of GIScience was provided in the report of a workshop at the National Science Foundation, Geographic Information Science, held in January 1999 (Mark 2003: 2): *"Geographic Information Science (GIScience) is the basic research field that seeks to redefine geographic concepts and their use in the context of geographic information systems. GIScience also examines the impacts of GIS on individuals and society, and the influences of society on GIS. GIScience re-examines some of the most fundamental themes in traditional spatially oriented fields such as geography, cartography, and geodesy, while incorporating more recent developments in cognitive and information science. It also overlaps with and draws from more specialized research fields such as computer science, statistics, mathematics, and psychology, and contributes to progress in those fields. It supports research in political science and anthropology and draws on those fields in studies of geographic information and society"*.

2. Related Work

A significant portion of the theoretical papers concerned with GIScience at least broach the subject of 'what is GIScience', whilst some are even entirely dedicated to the matter. The perhaps most significant paper concerned with delimiting the field of GIScience is the paper 'Geographical Information Science' by Goodchild (1992), in which the term was first introduced. In this paper, Goodchild indicates that there might be fundamental issues associated with the use of GIS technology and, therefore, highlights a need for theoretical foundations of GIS. Furthermore, he goes on to categorize the key issues to be addressed by GIScience, one of several attempts at defining a GIScience research agenda. Twenty-odd years down the track Goodchild revisits the fundamental issues of GIScience, and establishes what progress has been made in the field. His findings were published in the paper entitled 'Twenty years of progress: GIScience in 2010' (Goodchild 2010), where he also revisits the research agenda of GIScience, proposed in his earlier paper. Furthermore, Mark (2003) explores the significance of GIScience by exploring its historical roots, its context within the information sciences, as well as examining key players and components of the field. Other papers such as Agarwal (2005), for instance, address the need for a shared ontology in order to define GIScience as a field. They state that *"it is important that a common framework for ontology development in GIScience is determined so that all research initiatives can work in conjunction with each other and contribute to the development of a shared resource"* (Agarwal 2005: 502). In the following sections I will address the history of GIScience, as well as its context within both science and geography, based on related work, in order to establish a clear understanding of what is encompassed under the term 'GIScience'.

3. The History of GIScience

In order to fully understand the role of GIScience, it is essential to take a look at its roots and development. The necessity for GIScience lies in GIS technology, which is anchored within the broader framework of geography. Although GIS were devised in the 1960s, it wasn't until the 1980s, by which time GIS had assumed much larger dimensions, that anyone saw a need for a GI *Science* (Goodchild 2004).

3.1. The Relationship Between GIScience, GIS and Geography

The relationship between GIScience and Geography lies in the realm of GIS technology, since GIS emerged as a sub-discipline of Geography and GIScience emerged as a result of the inherent conceptual shortcomings in GIS. A summary of the critique directed at the field of GIS from the late 1980s until the mid-1990s can be found in Table 1.

Table 1: Timeline of GIS-Critique

1988	• President of the Association of American Geographers referred to GIS as "nonintellectual expertise"
1990	• Taylor suggests that GIS are *"inadequate in the realm of knowledge production, concerned with facts but incapable of meaningful analyses"*
1991	• As a response to Taylor, Goodchild (1991) argued that *"GIS has made its own limitations an integral part of its research for decades"* • Openshaw proposes GIS as an interdisciplinary field, incorporating human geographers
1992	• Gordon Clark suggests GIS is an emerging industry with commercial interests
1993	• Robert Lake picks up the thread of criticism initiated by Smith regarding epistemology and positivism
1994	• Sui responds from within the GIS community stating that the GIS community is aware of the conceptual shortcomings of GIS and is addressing the ethical issues raised by GIS
1995	• Pickles' book 'Ground Truth' is published which is a collection of articles criticizing the ethical and social implications of GIS software

After the decline of the discipline of Geography around the mid-twentieth century, marked by several internationally renowned North-American Universities closing their Geography departments (Harvard, the University of Michigan, the University of Chicago, Columbia University, amongst others), the emergence of GIS technology seemed to offer a new glimpse of hope for the subject (Goodchild, 2007). Goodchild (2007) is certain that the revival of the discipline of Geography is largely owed to GIS. However, the relationship between GIS and Geography was initially quite hostile. For example, in 1988 the president of the Association of American Geographers referred to GIS as being "nonintellectual expertise" (Goodchild, 2007) and two years later Peter Taylor published an editorial entitled 'geographic knowledge systems' in which he suggested that GIS are *"inadequate in the realm of knowledge* *production, concerned with facts but incapable of meaningful analyses"* (Taylor in Schuurman, 2000: 572).

In response to Taylor's critique, Goodchild (1991) argued that *"while the technological structure of GIS is controlled by computer science, the development of GIS in geography has led to the realization that databases and processes can be inaccurate.* He suggested that *"GIS has made its own limitations an integral part of its research for decades",* as stated in Schuurman (2000: 572).

Then, in 1991, Stan Openshaw published an article entitled 'A view on the GIS crisis in geography, or, using GIS to put Humpty-Dumpty back together again' in which he proposed GIS as an interdisciplinary field, whilst still incorporating human geographers (Schuurman, 2000). As opposed to Taylor, Openshaw saw the interdisciplinarity of GIS as a positive aspect, rather than seeing it as a threat to Geography (Schuurman, 2000). He emphasized that the *"technologies encompassed in GIS reflect a social shift that cannot be contained within geography"* (Schuurman, 2000: 573).

Subsequently, Gordon Clark wrote an article entitled 'GIS – what crisis?' in 1992, in which he dismissed the previous discussion and identified a whole new issue of GIS. He suggested that rather than viewing GIS as a (sub)discipline, it should be looked upon as an emerging industry with commercial interests and that it may well threaten the 'blue sky' research conducted by Universities. Clark concluded that *'it is going to become crucial for universities to identify some comparative advantage in the GIS market not easily penetrated by commercial companies'. From this perspective, squabbles within geography lose relevance'* (Clark in Schuurman, 2000: 574)

In 1993 Robert Lake picked up the thread of criticism initiated by Smith concerning epistemology and positivism. He defined positivism as encompassing *'assumptions of objectivity, value-neutrality, and the ontological separation of subject and object'* (Lake, 1993: 405). And subsequently built his critique of GIS on three main arguments, namely, *1) GIS is inherently positivist; 2) that its ethics are objectionable because they derive from positivist assumptions; and 3) that the 'subject–object dualism underlying' GIS is a positivist legacy.* (Lake in Schuurman 2000: 575). Lake also suggested that reconciliation between GIS and Geography would only be possible if GIS is willing to incorporate a theoretical basis so far missed by its critics (Schuurman, 2000). He stated that *'[b]reaching the divide at the core of planning and geography will be possible only to the extent that the developers of Geographic Information Systems are willing to relinquish their positivist assumptions'* (Lake, 1993: 405).

Sui (1994) was the first to respond from within the GIS community and he acknowledged and addressed the concerns of the critics. He stated that the GIS community had undergone broad efforts in order to address the ethical shortcomings and concluded that *'[t]hese efforts speak one thing loud and clear: that is, the GIS community has realized that the implementation of GIS should go beyond mere technical decisions justified by matters of efficiency and give the ethical use of this information technology a serious consideration'* (Sui, 1994: 271).

Then, in 1995, John Pickles assembled and edited a book by the name of 'Ground Truth: The Social Implications of Geographic Information Systems'. The book is basically a collection of articles, written by several authors, concerned with the possible social implications of Geographic Information Systems. The book addressed many weaknesses of GIS and the way they were being implemented, from a social perspective. It pointed out, for example, how GIS were being used to further empower those already in power, whilst marginalizing others. As a direct result of this issue, addressed in 'Ground Truth', the field of Participatory GIS emerged (Goodchild, 2006). This example demonstrates the importance of critique for the positive evolution of a domain, as is also pointed out by Pickles in a later publication (Pickles, 1999) in which he commented on the earlier debates regarding GIS as follows: *"Debates over GIS in Geography were overt and apparently motivated by a genuine desire on both sides to steer the discipline in an appropriate and responsible direction, despite occasional outbreaks of hostility"* (Pickles in Schurrmann 2000: 571).

3.2. Various Approaches to a Research Agenda

In 1984 Ron Alber joined the National Science Foundation (NSF) as the Program Director for the field of Geography and Regional Science. He envisioned financial NSF support for a science and technology research centre devoted to GIS (Mark, 2003). He wrote the NSF solicitation for the National Center for Geographic Information and Analysis (NCGIA), and defined five key research topics which the NCGIA should address (Abler, 1987):

- spatial analysis and spatial statistics;
- spatial relations and database structures;
- artificial intelligence and expert systems;
- visualization;
- social, economic, and institutional issues

According to (Mark, 2003: 4), these five points *"might now be seen as the first definition of the scope of an emerging new research field, that later became known as Geographic Information Science"*. At that time, researchers were actively engaging in debates about the intellectual merits of GIS and in 1990 Michael Goodchild held a keynote speech entitled 'Spatial Information Science' at a Spatial Data Handling conference in Zurich, Switzerland. His talk was later published under the title 'Geographical Information Science' (Goodchild, 1992) in the International Journal of Geographical Information Science. This paper marked the initiation of the term GIScience. In it, Michael Goodchild introduced the 8 following topics, which he later referred to as his proposed research agenda for GIScience (Goodchild, 2010):

- Data collection and measurement;
- Data capture;
- Spatial statistics;
- Data modeling and theories of spatial data;
- Data structures, algorithms, and processes;

- Display;
- Analytical tools; and
- Institutional, managerial, and ethical issues.

Furthermore, the NCGIA had been discussing the need for a more specialized group of researchers in the domain of GIScience in the early 1990s, so in December 1994 a founding meeting of the University Consortium for Geographic Information Science (UCGIS) took place in Boulder, Colorado, marking yet another milestone in the development of GIScience (Mark, 2003). In June 1996 the UCGIS defined 10 research topics central to their organization, which represent their GIScience research agenda (Mark, 2003):

- spatial data acquisition and integration;
- interoperability of geographic information;
- distributed and mobile computing;
- future and development of the spatial information infrastructure;
- extensions to geographic representations (beyond two-dimensional, single-resolution maps);
- cognition of geographic information and ease-of-use issues (the need to overcome the gap between human cognition and GIS if it is to be regarded by the general public as easy to use or introduced to young children);
- scale;
- uncertainty in geographic data and GIS-based analyses;
- spatial analysis in a GIS environment; and
- GIS and society (ethics, privacy). (National Academies Press 2006)

On the contrary to the schools of thought previously proposed by the UCGIS and Michael Goodchild, the NCGIA submitted a proposal entitled "Advancing Geographic Information Science" in 1995, which defined a new way of looking at the field of GIScience (Mark, 2003). In this approach, each research topic is seen as a combination of three aspects, namely, the computer, the user and society, located within the framework of a triangle, with GIScience at the core (Goodchild, 2010)

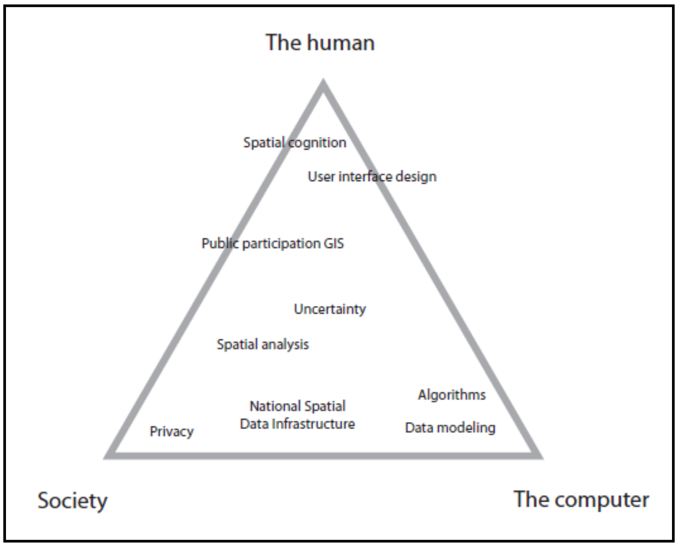

Figure 1. A conceptual framework for GIScience

According to Mark (2003) this approach seems rather unbalanced, as compared to the previously mentioned agendas; he feels that herein the computational components are played down (Mark, 2003).

4. A Common Research Agenda?

When comparing the two research agendas proposed by the UCGIS and Michael Goodchild, respectively, several points can be found which are in accordance with one another. For example, the points shaded in grey in Table 2 are common to both lists, however, vary slightly in the phrasing (Mark, 2003). Furthermore, with the exception of the first point, namely, data acquisition, these points also closely relate to some of the points suggested in the NSF's NCGIA solicitation, more specifically, spatial analysis and spatial statistics, visualization, and social, economic, and institutional issues.

Furthermore, the aspect of Visualization and Display, which was identified as a key research topic by Goodchild (1992), was recently also acknowledged as an emerging research topic by the UCGIS, although it was not included in their initial research agenda dating back to 1996 (Mark, 2003). However, although some of the points on Goodchild's list coincide with those identified by the UCGIS, several others are disregarded in at least one of the agendas.

Table 2. A comparison of the GIScience research agendas proposed by Michael Goodchild (1992,) and the UCGIS (1996), respectively.

M.F. Goodchild (1992)	**UCGIS (1996)**
Data collection and measurement	spatial data acquisition and integration
Data modeling and theories of spatial data	extensions to geographic representations
Institutional, managerial, and ethical issues	GIS and society (ethics, privacy)
Analytical tools	spatial analysis in a GIS environment
Spatial statistics	interoperability of geographic information
Data capture	distributed and mobile computing
Visualization and Display	future and development of the spatial information infrastructure
Data structures, algorithms, and processes	cognition of geographic information and ease-of-use issues
	scale
	uncertainty in geographic data and GIS-based analyses

I think it is safe to say that a research agenda for a domain as dynamic as GIScience requires constant updating and maintaining, due to the rapid emergence of new GIS technologies and the therein inherent issues raised for the underlying science. GIScience is a rapidly growing domain with an ever increasing number of stakeholders interested in contributing to the field. It is therefore not surprising that there are various approaches to a research agenda, and that these may differ in several points. A possible solution to such a plurality of approaches would be to assign a committee, responsible for keeping the agenda current, in regard to the emergence of both new technologies as well as new literature.

Haklay (2012: 479) criticizes the GIScience research agendas by stating that "while these agendas might seem like a coherent body of topics that set the direction of research within the discipline of GIScience, arguably these are not forward-looking but more stock-taking exercises". He argues that GIScience is merely a reaction to GIS technology, rather than an innovative field of research and therefore labels it as an inclusive research approach (Haklay, 2012). Furthermore, Haklay (2012: 480) believes that "the research agenda is shaped by societal and technological changes, and the people that are involved in GIScience research seem content to include new research avenues". He argues that GIScience eventually incorporates such new "research avenues" into its research agenda, even if it encounters initial critique within the GIScience community. He gives the example of critical GIS, which is nowadays a legitimate aspect of GIScience, however, was initially faced with a great deal of controversy (Haklay, 2012).

5. Is GIScience a Science?

The ongoing debate surrounding the question of whether GIScience is a science or not, is nearly as old as the field itself. Therefore, it has received much attention in literature, and is a commonly discussed theme among GIScientists, who feel the need to defend their discipline to outsiders and to promote it as a justifiable field of research and teaching (Reitsma, 2012).

5.1. Defining Science

In order to determine whether GIScience is a science or not, it is perhaps essential to look at the bounds of the term 'science' itself. However, these are by no means clearly or uniformly defined, a problem which is commonly known as the 'demarcation problem' (Reitsma, 2012). The demarcation problem constitutes the issue of separating science from pseudo-science, anti-science or para-science. This problem has historically been based on the discordance of defining science based on a scientific method, as opposed to a universal set of sufficient demarcation criteria (Reitsma, 2012). However, defining science based on a scientific method raises an entirely new debate as to the nature of a scientific method, which has been broadly discussed, yet hasn't resulted in a uniform or coherent conclusion. Reitsma (2012: 5) states that *"if we agree that science lacks a definitive and objective methodology, we might happily throw GIScience in the melee, yet we have not yet solved the problem of demarcating science, if it cannot be done on its method".* Assuming the alternate means of defining science, namely, based on a universal set of demarcation criteria, is also problematic, since most philosophers doubtfully regard the existence of a set of sufficient conditions which may be used to demarcate science from non-science (Reitsma, 2012). Thus, there is increasing agreement on the fact that there may not be any clearly definable criteria for demarcating science, which subsequently means that there is no consensus about the nature of science itself (Reitsma, 2012). Nevertheless, there are a number of criteria, which an increasing number of philosophers of science agree on as being central to demarcating science. Such key criteria include, for instance, simplicity, predictive accuracy, coherence with known facts, as well as testability (Stamos, 2007).

5.2. The million-dollar question: Is GIScience a science?

Given that there seems to be no clear demarcation of science itself, placing GIScience under the umbrella term of science is a difficult task and can be approached in various manners. One such approach was taken by Reitsma (2012), who compared some examples taken from the field of GIScience against the key criteria specified above. Another approach was taken by Goodchild (2004 b) who bases his arguments on Anselin's concept of spatial heterogeneity and Tobler's first law of Geography and points out that GIScience has law-like statements. Furthermore, it has been argued that GIScience is based on inductive methods, which leads me to reason that it may belong to the humanities rather than the natural sciences. In the following section I will outline and discuss these three different approaches of justifying GIScience as a science, as well as examining the importance attached to being labeled as a science.

5.2.1. Comparing key-criteria of science to case examples from GIScience

The first key-criterion examined by Reitsma (2012) is the aspect of s*implicity*. In this context, the term simplicity is considered as a guiding principle for the evaluation of rivaling theories, in order to select the best theory, whereby the simplest theory is considered best (Reitsma, 2012). *"In the context of GIScience, where our theories are about geographic information, we can consider the move towards identifying simpler theories for representing geographic phenomena, space and time as an example of an aim towards simplicity"* (Reitsma, 2012: 7). For this aspect, Reitsma (2012) adds the example of Goodchild et al. (2007) *"developing a primitive data model for geographic features"* (Reitsma, 2012: 7).

The second criterion examined by Reitsma (2012) is that of *predictive accuracy*, where she argues that the nature of GIScience is information, and that its inherent duty is to predict. Specifically, she highlights the role of GIScience for making predictions about information itself, or about methods which involve the use of information. She gives the example of spatial interpolation, where locational values are predicted based on their relation to other locations with known values (Reitsma, 2012).

The next criterion examined by Reitsma (2012) is that of *coherence*. She defines coherence as *"the relationship between hypotheses or theories, or the relationship between those hypotheses or theories and things they are trying to represent"* (Reitsma, 2012: 8). As an example of coherence in GIScience she draws on the 9-Intersection Model presented by Egenhofer and Franzosa (1991), which describes topological relationships between two regions.

The last key-criterion presented by Stamos (2007) is that of *testability*. With regard to this concept, Reitsma (2012) argues that since geographic information is persistent and repeatable, GIScience theories inherently fulfill the premise of testability.

Reitsma (2012) concludes that GIScience may well pass as a science, if defined on the basis of the key-criteria identified by Stamos (2007), as it contains significant aspects of most criteria. However, she goes on to mention that it is difficult to define a science based on a small list of criteria, since there may well be further noteworthy criteria to be considered such as, the generality of results (Reitsma, 2012). She also notes that *"in contrast to most other sciences, GIScientists do not study the world, rather the representations of that world. GISc considers how these representations, how geographic information, are formed, collected, managed, analysed and visualised. As such, GISc cannot exist independently from the other sciences. It exists in symbiosis with other disciplines, such as geography and psychology, which guide data collection and other information needs"* (Reitsma, 2012: 9).

5.2.2. The validity of laws and principles in GIScience

Goodchild (2004 b) states that *"all fields of scientific activity serve to simplify the world around us through the identification of general principles (...)"* and from this, draws the conclusion that *"principles therefore form the foundation of most learning in science"* (Goodchild, 2004 b). Therefore, Goodchild (2004 b) attempts to justify GIScience as a science on the basis of its dependence on scientific laws and principles.

The first law he addresses is Tobler's first law of Geography (TFL), which states that "Everything is related to everything else, but near things are more related than distant things" (Sui, 2004). Although TFL is formulated in a simple, rather non-scientific manner, Goodchild (2004 b) argues its essential value for GIScience by stating that *"all of our methods for simplifying and describing the geographic world, and working and moving within it, rely on the validity of TFL".* More specifically, he attributes aspects such as generalization, interpolation, resampling, contour mapping, the value of GIS data models, as well as structures such as the quadtree, to the validity of TFL (Goodchild, 2004 b).

Furthermore, Goodchild (2004 b) introduces a number of other scientific principles, which he considers to, amongst others, constitute the foundation principles of GIScience (Goodchild, 2004 b). For instance, he mentions the fractal principle which states that "*geographic phenomena reveal more detail the more closely one looks and that this process reveals additional detail at an orderly and predictable rate"* (Goodchild, 2004 b); or the principle that *"two distinct conceptualizations of geographic information are possible as collections of countable, discrete objects littering an otherwise empty space and as a finite set of continuous fields, or functions of location"* (Goodchild, 2004 b). Moreover, he mentions the uncertainty principle, which states that *"the geographic world is infinitely complex and that any representation must therefore contain elements of uncertainty, that many definitions used in acquiring geographic data contain elements of vagueness, and that it is impossible to measure location on the Earth's surface exactly"* (Goodchild, 2004 b).

Goodchild (2004 b) concludes that the merits of GIScience as a science are indeed attributed to the foundation on such, and many more, scientific principles. However, he concedes that there is currently little consensus as to the underlying principles of GIScience and that it is *"hard to find clear statements of the founding principles of the emerging discipline of GIScience as it is to find clear statements of the founding principles of Geography"* (Goodchild, 2004 b). Therefore, although Goodchild (2004 b) is convinced of the validity of GIScience as a field of science based on its foundation on scientific principles, these are not universally recognized as adequate criteria and therefore the debate may well continue.

5.2.3. GIScience as a Social Science?

As reasoned by Haklay (2012) in his paper entitled 'Geographic Information Science: Tribe, badge and Sub-Discipline', the field of GIScience is based on an inductive, rather than deductive approach. While deductive methods begin with a theory, which is then extended to a hypothesis, and subsequently either confirmed or discarded depending on the observations (tests) carried out (Fig. 2), inductive methods work the other way around, building theories on the basis of observations (Fig. 3). Inductive approaches (also referred to as 'bottom-up' approaches), work with initial observations and, based on these, aim to detect patterns and regularities which may then lead to the formulation of hypotheses and, ultimately, theories.

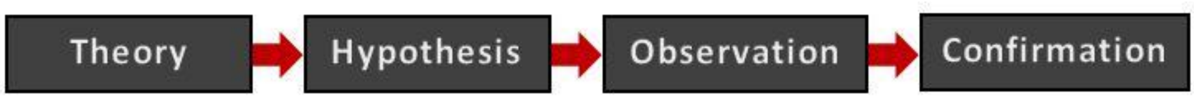

Figure 2: Deductive „Top-Down" Workflow

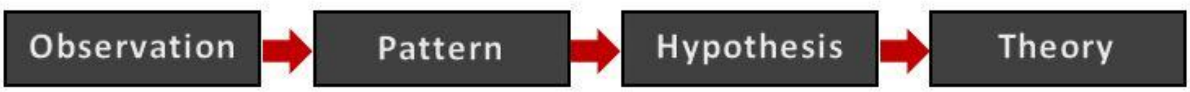

Figure 3: Inductive „Bottom-Up" Workflow

Max Born, a famous Nobel-Prize winning physicist stated in his book, entitled 'Natural Philosophy of Cause and Chance' (1949:5), that *"Induction allows us to generalize a number of observations into a general rule".* He goes on to argue that although there is no definite criterion for the validity of an inductive rule, there is a scientfic code which defines the criteria necessary for validifying an induction. However, he refrains from specifying what such a code may entail and stresses that it may well be rejected by other members of the scientific community since there is *"no logical argument"* to *"compel them to accept the same criteria of valid induction"*, rather it can be considered as *"a question of faith"*. Therefore, he concludes that induction may be considered as a meta-physical principle, *"namely something beyond physics"* (Born, 1949:7)

In this context, one could argue that a discipline which is based on inductive principles may be more suited within the realm of the humanities, rather than the natural sciences. As defined by Longmans Dictionary of Contemporary English, Science is *"knowledge about the world, especially based on examining, testing, and proving facts".* In this sense, one would expect a field considered as a science to work in a deductive manner, i.e. formulating theories and hypotheses and then examining, testing and proving these in order to be able to either confirm or reject them.

If we think about the processes which take place in GIScience, however, it becomes evident that it does indeed – at least partially – implement an inductive workflow. GIScience develops methodologies to address problems or research challenges which arise as a result of the emergence of new GIS tools and technologies (Haklay, 2012). These methodologies may then in turn lead to the development of a founded theoretical understanding of both the technologies themselves, as well as the impacts these have on society (Haklay, 2012). For example, GIScience addresses issues of ethics and privacy which emerged as a direct result of the development and implementation of GI-Software. The issue of ethics and privacy were addressed in both the research agenda by the UCGIS, as well as that by Michael Goodchild and therefore seems to be a key-theme of GIScience.

For this reason, I herein argue that GIScience cannot soley be considered as a natural "hard" science. Rather its close ties to the humanities must be acknowledged, both on the basis of its inductive nature, as well as its thematic links to social science disciplines. However, certain other brances of GIScience most certainly have a place within the "hard" sciences, as demonstrated by Reitsma (2012) and Goodchild (2004 b). This leads me to conclude that GIScience is of dichotomic nature, rather than being a coherent whole, which can be placed under the umbrella term of "science" or "humanity".

5.2.4. The Significance of Defining GIScience as a Science

According to Reitsma (2012), it is important to justify the field of GIScience as a science in order to receive funding from agencies. She states that funding agencies favor "hard" sciences which work with empirical methods and produce substantial results, as opposed to "soft" sciences, whose contribution is often not sufficiently recognized (Reitsma, 2012). Furthermore, Wright et al. (1997) argue that the term "science" is often used synonymously with the term "research" and that it therefore functions as a *"crude but convenient shorthand for academic legitimacy"* (Wright et al. 1997: 354). They go on to state that *"if 'doing GIS' is 'doing science' then its claim to a place in the academy, as a topic of research and graduate-level instruction, is clearly strengthened"* (Wright et al. 1997: 354). Reitsma (2012) also points out that underpinning the label of science leads to more credibility for arguments or evidence gained within a field, and therefore states that there may well be good reason for *"a bit of scientific gerrymandering"* (Reitsma, 2012: 9) in order to include GIScience within the realm of sciences.

6. Evaluation

As demonstrated in section 3, the birth of GIScience did not progress without further complications. On the contrary, the initial phase in the early 1990s was marked mainly by discordant views by various key players from both within and outside of the GIS community. There was an evident need for a science behind the systems as the rumblings about GIS technology grew ever louder. How exactly this science was to be defined raised a series of issues, some of which still remain unsolved. The exact role of GIScience was addressed within the framework of various research agendas, which constitute the basis for the domain. These research agendas are, however, neither unified, nor current, which is, in my opinion, a major shortcoming in such a rapidly evolving field. In order to adequately address all current issues being raised by GIS technology, such an agenda would have to be (at least) annually updated and discussed amongst the GI-Community. The problem, however, in my eyes, lies in the lack of cooperation between key players, each of which is brewing up own definitions and concepts, whilst both citing and criticizing other literature. It seems to be an endless circle, constituted of a jungle of citations, but in many cases lacking distinct results. Many publications merely cite and discuss predecessing publications in an attempt to continue an ongoing debate, rather than to offer new insights which would contribute to the body of knowledge. GIScience has neither a unified definition, nor a unified research agenda, and not even a unified view regarding whether or not it can be considered a science. I think it is precisely this uncertainty from within the GIScience community which leads to criticism of the field. If GIScience is not in a state to present a unified front to the 'outside world' then its credibility may well be compromised. It must also be noted, however, that the discipline is still in its infant stage and that it is likely that the remaining discordance will be solved as it becomes more established, as stated by Agarwal (2005: 502) *"since GIScience is itself an evolving discipline, the boundaries of, and within, this discipline are not yet well defined".*

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7. Conclusion

In summary, and in an attempt to answer the proposed research questions, namely 'what is GIScience – what is GIScience NOT', I may conclude that despite the myriad of definitions, GIScience is in essence indeed the "science behind the systems" (Goodchild 1992: 32). Its specific research topics, however, are subject to constant change due to the rapid evolution of technology. Therefore, delimiting borders for the field would perhaps have a constraining effect, rather than solidifying its place within the scientific community. However, a coherent and current set of objectives and topics wouldn't go astray, especially in such a dynamic field. GIScience offers the theoretical foundations and addresses a multitude of issues which go hand in hand with GIS technology. Therefore the relationship between GIS and GIScience can be viewed as a circuit of action and reaction. Through the practical application of GIS, problems surface which were priorly not considered, and these are subsequently addressed by GIScience. In turn, GIScience serves to offer new insights to the GIS community, which can then be integrated in the development of new tools and technologies. However, while the practical application of GIScience is delimited by the bounds of GIS, the theoretical principles are closely intertwined with aspets of social science such as philosophy and ethics.

In regard to the question of whether GIScience can be considered a science or not, I think that the two publications discussed in section 5 are valid contributions for the justification of GIScience as a Science. The arguments raised in both papers seem legitimate and therefore lead me to the conclusion that certain aspects of GIScience indeed have a claim to a place in science. However, as noted earlier there are also substantial aspects of social sciences included in the field of GIScience, which make it impossible to place the discipline as a whole under the umbrella of science. Rather it would have to be split into a social and a natural science aspect, in order to fit into either of these categories. Whilst this is not the case, however, the place of GIScience within the bigger picture of sciences will remain disputed, and GIScientists will inevitably have to continue to defend and justify their discipline to the 'outside world'.

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