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Research Article

Spatial Causalities in Geographies of Scientific Knowledge

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Keywords

Geographies of science, Spatial causalities, Spatial turn, Geographic algorithms

Abstract

This paper tries to discuss the efforts of geographers of science to put science in its geographical contexts. Geographers of science have studied the socio-spatial settings in which scientific knowledge has been generated, displayed, and legitimated. For them, science is socially constructed in "spatialities" and "temporalities". The major question of this study is how "spatialities" construct scientific knowledge via its "causalities". The fundamental idea is that geography of science does not only deal with places, locations, and regions where scientific knowledge is produced or distributed; it also deals with a variety set of spatial causalities through which scientific knowledge can be formed and transformed. This means that the development of innovative knowledge and ideas take place not only within a spatial context but also occur due to the spatial causalities associated with the myriad interlinkages and interdependencies among places. These imperatives of spatial significance operate across many spatial scales from body/local to the planet/global. Hence, in our increasingly globalized world, we must seek knowledge in spatial encounters and in-between places, not merely within spaces and places. In addition, when we are living in an unprecedented transformation period which transfers the terrestrial spatial causalities to the virtual spatial causalities via intelligent and digital technologies, we should be more aware of the difference that new algorithms make in our daily life through hacking virtual spatial causalities.

Highlights:

- Any history of science has its own geography.

- Geography of science does not only deal with places and regions where scientific knowledge is produced or distributed; it also deals with a variety set of spatial causalities through which scientific knowledge can be generated and transformed.

- When we are living in an unprecedented transformation period which transfers the terrestrial spatial causalities to the virtual spatial causalities, we should be more aware of the difference that new algorithms make in our daily life.

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1. INTRODUCTION

"Space is rapidly becoming a central organizing principle for making sense of scientific knowledge." (Livingstone, 2010)

Geographers of science, nearly simultaneously with growing prevalence of "spatial turn" in the science studies, begin to review ways in which space has become a central organizing principle for examining the production, circulation, and consumption of scientific knowledge. David Livingstone (1995) (among others) was one of the first geographers who captured this issue brilliantly and tried to outline a "historical geography of science".

Livingstone (1995) has argued that the historians of geography have taken so little account of the spatial dimensions in the histories they have produced. Indeed, they overlook the importance of the spatialities in the generation, justification, diffusion, and application of new geographic knowledge itself. Even some historians of geography who put efforts to write the history of geographical knowledge/theories, ignored the geography of geographical knowledge/theories or restricted to the great extent their survey with regard to the geography of one particular space (time arena), and then generalizing their findings.

For Livingstone "scientific knowledge is made in a lot of different places. [But] does it matter where? Can the location of scientific endeavour make any difference to the conduct of science? And even more important, can it affect the content of science? [for him], the answer to these questions is yes" (2003, p. 1). So, as Withers (2002, p. 9) also argued, "If we can have a history of science, a philosophy of science and a sociology of science, why not a geography and, even, a historical geography of science?" Undoubtedly, this is a great idea, but how we can prove it, particularly in the "new" condition of geographies of science.

The first lesson we learned from geography of science was that the historians of geography have failed to attend to the spatial components of their discipline's history in one sense; that is the history of geography has frequently been written with little reference to the placing of geographical knowledge in its various spatial contexts or putting this science in its place. This approach may be justified by the widespread assumption corresponding with the securing credibility and achieving objectivity which requires "placelessness" (Livingstone, 1992; 1995; 2003). Placelessness in science means that, we must go beyond geography, but it has well accepted that we are not outside or beyond geography and we are not free from the struggle over geography (Said, 1993). As the historian of science Bruno Latour (1993) said, if aspatiality is modernity, we are not and have never been modern.

Although, I agree with these sort of strategies that some geographers proposed, but, I think this is not enough if we want to prove the differences that spatialities make in geographies of science particularly in the dominance of globalization and virtual spaces. Therefore, in continuing previous researches, one of the major questions we should always answer is how "spatialities" construct scientific knowledge via its "causalities"? The fundamental approach is that geography of science does not only deal with places, locations, and regions where scientific knowledge is produced or distributed; it also deals with a variety set of spatial causalities through which scientific knowledge can be formed and transformed.

For geographers, this means that the development of innovative knowledge and ideas take place not only within a spatial context but also occur due to the spatial causalities associated with the myriad interlinkages and interdependencies among places. In addition, when we are living in an unprecedented transformation period which transfers the terrestrial spatial causalities to the virtual spatial causalities via intelligent and digital technologies, how we can be more aware of the difference that new algorithms make in our daily life through hacking virtual spatial causalities.

This paper is based on the assumption that scientific knowledge has a spatial nature; it shapes and is being shaped by the spatiality; it further generates and is being generated by spatial encounters in terms of relational networks in a world which is under constant becoming. As such, this paper tried to show that the geographies of science are not simply about spatial disparities of knowledge, but also it deals with the role that "spatial causalities" can play in the generation of scientific knowledge.

Hence, given such a primal debate, this paper aims to explore the major findings related to project of spatialising historicality and sociocality, and echoes and resonances of these efforts in science studies and our understanding of scientific knowledge (part 2). It further emphasizes investigations of historian geographers in order to put science in its geographical contexts (part 3). Finally, It tries to provide an analysis of the "new" condition of geographies of science and examine how the spatial causalities operate in the terrestrial and virtual geographies simultaneously (part 4-5).

2. SPATIALISING SCIENTIFIC KNOWLEDGE

The interest in the historical and social contexts of scientific knowledge refers to Kuhn's work *The structure of scientific revolutions* in 1962 which now is considered 'science studies'. Recent literature within science studies has not only focused on the history of science, philosophy of science, and sociology of science but also geography of science. This spatial property of the science studies has provided the golden opportunity for the discipline of geography to be included in science studies.

Shifting attention to the geographies of scientific knowledge has received significant importance during the past two decades. However, no serious attention has ever been paid to the spatial aspects of scientific knowledge prior to the "spatial turn" in philosophy, literature, and humanities/social sciences. This era associated with the advent of some of the 1960s Parisians, including Foucault (1980; 1989), Deleuze (1984; 1987), and Lefebvre (1991), and the revival and expansion of their thought after the 1980s. In the late 1980s, as cultural and social studies experienced a spatial turn, geographers began experiencing a concomitant "cultural turn". The growing prevalence of geographicalism after the spatial turn is closely linked to the recognition of the key role of space in the processes by which people (re)construct their understandings of the world. The main concern in "geographicalism" is the spatiality of scientific knowledge (Shoorcheh, 2018). Therefore, the "geographical turn" is a kind of revealing of the infusion process of spatial vocabulary and languages into historical and philosophical accounts of scientific knowledge (Cook et al., 2000; Gulson and Symes, 2007; Finnegan, 2008; Warf and Arias, 2009; Nieuwenhuis and Crouch, 2017).

More recently, the proponents of this "geographicalism" in science studies have themselves utilized notions of spatiality and have followed the course of the "spatial turn". Major stimuli for a spatial turn in science studies originated partly from those studies of science that shifted their focus from problems of truth and validity toward issues surrounding the credibility of and trust in scientific experiments and the circulation of scientific results.

The central historical concerns for Foucault (1980; 1986; 1989) is associated with spatialising history via interaction between space, knowledge, and power. In general, his explorations of spaces of knowledge focus on the local, the specific, and the place-bound. These spaces include heterogeneous spaces such as the church, the theatre, the prison, the garden, the factory, court, cemetery, asylum and so on which these represent the sites and situations from which discourses of various discipline and punish technologies emanate. For Foucault, power/ knowledge is inscribed in spatiality, not in temporality.

Lefebvre (1991) argued that different societies create different spaces as an expression of their social structures and social relations. In other words, all social relations are spatial, and all spatial relations are social. Lefebvre's history was an anti-history. The brilliance of his argument in this regard can be seen in the *production of space* (1991) and *Urban Revolution* (2003) which paved the way for the more spatialising historicality and sociocalityin the following decades. He (1976) also argues that politics was first and foremost a question of the politics of space. Accordingly, the main thing that societies do is to produce space, just like that capitalism has found itself able to attenuate (if not resolve) its internal contradictions by occupying space, by producing a space. For Lefebvre (1996), politics was a spatial more than a historical practice, which is discussed in the concept of "the right to the city".

Said (1978) in *Orientalism* book has emphasized imaginative geography and further deconstructed the idea of the "Orient" (as a kind of alter ego to Europe) by demonstrating how it was produced politically, culturally, militarily, ideologically, scientifically and imaginatively via the West during the post-Enlightenment period. It is argued in this particular period, narratives are at the pivot of what explorers say about other geographies of the world. Said (1984) also based on the idea "travelling theory" has shown that ideas and theories travel-from person to person, from situation to situation, from one period to another. However, these circulations are never mere replications; they involve transformations due to the fact the theory has to be grasped in the geography and the history out of which it emerges. In his view, "just as none of us is outside or beyond geography, none of us is completely free from the struggle over geography. That the struggle is complex and interesting because it is not only about soldiers and cannons but also about ideas, about forms, about images and imaginings" (Said, 1993, p. 6).

Latour (1987) emphasizes on the mobility, circulation, and distant domination of scientific information by what he calls the "centres of calculation" (such as natural ecosystems, natural history museums, botanical and zoological gardens, geological cross-sections, photographic plates, computer printout, astronomical charts, terminal screens, scaled-down engineering models or scaled-up electron images of cells, statistical offices, and so on) which facilitate the mobilisation of information, and thereby domination at a distance.

Other works on historicism's blindness to the space after spatial turn have included Carter's concern with "the act of naming"- that is by the act of place-naming, space is transformed symbolically into a place, that is, a space with a history (Carter, 1987), uneven geographical distribution of science with ecological constructivism that prioritizes material environment over other factors in the production of scientific knowledge (Dorn, 1991), geographical turn in philosophy with emphasized on situating rationality (Casey, 1993), use spatial metaphors to define selfhoods and geography of social statuses and functions (Taylor, 1989) and positioned rationality with emphasizing what she calls "positioning in social space" and the view "from somewhere" instead of the "view from nowhere" mainly from a feminist perspective (Haraway, 1991).

Some social and anthropological theorists show how sociocality and spatiality are reciprocally constituted. They have also emphasized the crucial importance of place in structuring social interaction and spatiality of the human body in the routines of everyday life. The spatialities facilitating human assemblages and social interactions (Goffman,1969). "localist turn" in social and cultural knowledge/meaning by a comparative perspective and by a hermeneutic programme tries to show that ethnography is crafts of place. Accordingly, the meaning would take precedence over mechanism, and only by taking the localist turn can the piled-up structures of inference and implication begin to be unpacked (Geertz, 1983).

Other theorizing works in this field, like Giddens's interaction with spatial elements, has been directed towards the ways in which social systems are situated in space and time in terms of structuration theory and with a dialogue with the time-geography. In general, Giddens (1984) emphasises the constitutive agency of space and time in contextualizing social life and social institutions. He also argues, "locales are thoroughly penetrated by and shaped in terms of social influences quite distant from them. What structures the locale is not simply that which is present on the scene; the visible form of the locale conceals the distanciated relations which determine its nature" (1991, p. 19).

These studies have generally emphasized on our daily lives which are bound up with the paths we take through time and space (Urry, 1985), ordering social interactions across time and space (Turner, 1987), the topology of social spaces (Bourdieu, 1985, 1989); dead public space in modern society (Sennett, 1977) and the geography of truth (Burke, 2000). These studies have tried to explain that space is a problematic category because (social) spaces are produced as well as occupied. As Soja (1989) has argued, the production of space must be described as both the medium and the outcome of social action.

In recent decades, philosophy has been recognizing the importance of spatiality in philosophical reflections. Critiques of various forms of philosophical idealism and "ivory tower" philosophy have caused many philosophers to rethink the discipline and ground it in spatialities of everyday life and in urban policy forms. Hence, the city has re-emerged as a key political issue, given that recent trends in globalization have caused the urbanization of life for the majority of the world's population and the creation of megacities with economies and knowledge networks that dwarf most nation-states. This means that thinking about many issues in our world today is not possible without thinking about the importance of the spatial dimensions on determining the existence of humans, and the role that "spatial causalities" can play in philosophical reflections (Meagher et al., 2020).

All aforementioned endeavours reveal not only the power of spatialities in scientific knowledge but also the consciousness of human beings. To understand the nature of scientific knowledge then, we must necessarily grasp the inherent spatial aspects of being-in-the-world. It is critically important to pay attention to those places and spaces that have generated knowledge and then circulated and consumed it in different scales from body/local to the planet/global. At every geographical scale, "historicality", "sociocality" and "spatiality" are tightly interwoven (Soja, 1989; 1996) and form the fundamental ingredients of 'the trialectics of being'.

3. PUTTING SCIENTIFIC KNOWLEDGE WITHIN ITS GEOGRAPHICAL CONTEXTS

The geography of science and its relevant endowers has developed since the early 1980s mainly with Livingstone (1995; 3003); Naylor (2005a, b); Shapin (1991; 1998); Finnegan (2008); Powell (2007); Withers (2002; 2004) and Meusburger (2008). Their researches are basically rooted as well as inspired by theories of Michel Foucault, Henry Lefebvre, Edward Said, Pierre Bourdieu, Clifford Geertz, Anthony Giddens, Donna Haraway, and Bruno Latour. The pivot focus of these geographers is to prove that geography (place and space) deals with the production of scientific knowledge. They argued that scientific knowledge is socio-spatially constructed and scientific knowledge is never free of socio-spatial contexts and assumptions. It is known that the generation of scientific knowledge is situated within historicality, sociocality, and spatiality processes. This could be justified that acceptation of knowledge is based on rhetoric, persuasion skills, and power rather than established rules of discovering the truth.

However, the more scrutiny of spatiality in the late twentieth in the light of "spatial turn" was the major stimuli for new research questions about the role of geography within the process of knowledge production that also paved the way for development of what is now known as the "geography of science". Geography of science claims that science studies ought to necessarily be confronted the questions of spatiality. Therefore, as mentioned already, geographers of science try to review ways in which space has become a central organizing principle for examining the production, circulation, and consumption of scientific knowledge. For them, "the scientific sites and spaces, the movement and transformation of knowledge, and scientific regions ranging from the provincial to the continental have been significant foci of research" (Jöns et al., 2010, p. xi).

Livingstone in his book *Putting science in its place: geographies of scientific knowledge* (2003), draws attention to a number of ways of thinking spatially about scientific culture and a more spatially sensitive to the history of science. Livingstone argued that science is concerned with ideas and institutions, theories and practices, principles and performances. All of these have spatial dimensions (2003, p. 12). He has pointed out that scientific knowledge "takes shape in response to spatial forces at every scale of analysis - from the macropolitical geography of national regions to the microsocial geography of local cultures" (2003, p. 4). Since, in different spaces, different kinds of science are practiced (2003, p. 15). This means that every aspect of science is open to geographical interrogation.... There are always stories to be told about how scientific knowledge came to be made where and when it did (2003, p. 14).

Livingstone has described, although sites where experiments are conducted, the places where knowledge is produced/consumed, the localities where investigation is carried out (2003, p. 3), but the ideas and images travel from place to place as they move from person to person, from culture to culture. As ideas circulate, they undergo translation and transformation because people differently encounter representations in different circumstances (2003, p. 11). In short, in different locations, at different times, in different circumstances, and at different scales, space had made its mark on science in different ways (2003, p. 14).

He has chosen to dwell on three following dominant geographical motifs (site, region, and circulation) and their consequences with respect to science:

- *Sites*: including range widely from the laboratory to the zoological garden, from the field to the museum, from the hospital to the public house.
- *Regions*: including some of the ways in which regional cultures, provincial politics, national styles, and such have conditioned the practices and products of scientific endeavours.
- *Circulation*: it deals with the significance of the movement of specimens and instruments across space and time, or knowledge which travels from place to place.

Therefore, his book is organized spatially rather than temporally, geographically rather than historically. Within this framework, it departs from the conventional practice with emphasized upon prioritization of time over space with regard to thinking about the nature of science has received considerable attention (Livingstone, 2003, p. 14).

Naylor (2005b, p. 3) considers three domains of geographies of science: The first one is the micro-geographies of science which is associated with intimate and mundane spaces; the second one and its corresponding contexts include the city, the region and the nation; The third one focuses on a more general and perhaps more abstract set of geographies, those that help define the contours of science itself - what we might term 'cartogra-phies' of science.

Shapin (1998, p. 5) argued that the truth is – and, arguably, always has been – the ‘view from nowhere’. He claims that the view in which the knowledge is geographically located will depart us from the fact the knowledge in question is not authentically true at all. This in turn lead us to this idea that rise of a geographical perspective on science in recent years is so remarkable. He believes in that knowledge is made and sustained through situated practical activity. However, we must emphasize localist perspectives on making, meaning, and evaluation of scientific knowledge. For Shapin (1998, p. 5), the efficient spread of scientific knowledge is not a phenomenon that is against of the applicability of geographical sensibilities towards science, rather it actually calls for an even more vigorous project in the geography of knowledge.

For Finnegan (2008, p. 371-373), sites, regions, territories, and boundaries imply, on first thought, a static account of the geography of science (science in situ) which may ignore the geographies described by science on the move…. But it has been suggested that the circulation of scientific knowledge, instruments, personnel and objects should be carefully charted and accounted for (science in motion). He added which space need not be thought of as a container or backdrop for social life – a view often described as an abstract Cartesian notion of geometric space – but rather as an active ingredient in social and cultural life or an inescapable (which is not say uniform) mode of existence. This relational view of space has provided grounds for integrating more fully geographical and sociological accounts of science and has been widely adopted by scholars explicitly concerned with developing historical geography of scientific knowledge.

Powell (2007, p. 310) argues that, due to a concern for the credibility of truth-claims and truth-claimants, science studies necessarily had to be confronted questions of spatiality. He examines the geographical approaches that have been evident in science studies including among those who conceive the sites of scientific practice as a social arena which is well exemplified itself in architectural studies; ethnographic and ethnomethodological (studies of laboratory spaces); post-humanist theories of practice (actor-network theory); and discussions

about normative proposals (post-colonial science studies). In doing so, he thus argues that different geographies of science are emerging.

The spaces of scientific knowledge such as laboratory, universities, research and statistical institutions, museums (as key examples of scientific sites), however, are certainly not the only spaces in which scientific action takes place. Indeed, when it is said that the production of scientific knowledge, its character, its conditions and content, is an inherently spatially organised activity, this means that we need to focus on the spaces of (re)production scientific cultures.

Spatiality in geographies of science is also defined as a causality via which certain kinds of "cultures of knowledge" are bolstered. Culture of knowledge is created through socio-spatial interaction that is not only in formal education but also in informal education as well, where social relations evolve and where identities, goals, beliefs, attitudes, cultural preferences, discourses, stereotypes, and social inequalities are produced or reproduced. From the viewpoint of geography, the diffusion and circulation of knowledge cannot be reduced to the mere transmission model of information (senders of information and receivers of information). Unlike information, which is very mobile and can spread all over the world, knowledge is rooted in persons, institutions, routines, and regional cultures (Meusburger, 2008).

As Meusburger (2008, p. 73-74) argued, knowledge can be distinguishably differentiated into at least five categories as far as the speed and places of their diffusion is concerned:

1. Knowledge that is kept secret as long as possible and is necessary for gaining a competitive advantage.

2. Knowledge that is widely disseminated in the interest of its producer, though a number of barriers may impede its diffusion (e.g., a sender's difficulty expressing his or her knowledge in language, signs, gestures, or performance, or insufficient attention attracted by the platform on which the knowledge is presented).

3. Knowledge that is successfully codified and publicly available but understood, processed, and applied only by a relatively small epistemic community with the prior knowledge necessary to read the code (e.g., foreign language or mathematical equation) in order to comprehend the message or replicate the experiment.

4. Knowledge that is successfully codified, well documented, open to the public, and well understood by the addressees but not accepted or adopted by a distinct group of recipients for emotional or ideological reasons.

5. "Common knowledge" that is easily articulated and disseminated, easily acquirable, promptly understood, and relatively conflict free, making it the only one of these five categories of knowledge that is as mobile in space and as ubiquitously distributed as hypothesized in traditional economics.

It goes without saying that combinations of these five types also exist (Meusburger, 2008, p. 74). It is obvious that each stage of the diffusion and circulation process of knowledge has a high degree of spatiality-dependent contingency.

Other more recent approaches in geography such as "critical physical geography" and "critical GIS" and GIScience" have shown some interest to elevate spatiality to new levels of material and immaterial significance in geographies of science. For example, in Whatmore's (2002) view, science studies provide fertile grounds for geographers in developing new social and natural imaginations together. The idea of Critical Physical Geography (CPG) which was developed in the early 2010s by a cohort of geographers has emphasized on the spatialising of nature. Critical Physical Geography is an emerging body of work that brings together social and natural science in the service of eco-social transformation, combining attention to power relations and their material impacts with deep knowledge of particular biophysical systems. By

studying material landscapes, social dynamics, and knowledge politics together, Critical Physical Geography answers the periodic calls for integrating geographic research. This mission is associated with the explosion of interest in "the Anthropocene" and the widespread understanding that the material world is now shaped by deeply intermingled social and biophysical processes. It is argued that if the biophysical world which surrounds us is now an eco-social hybrid therefore our research possesses this property (Lave et al., 2018).

The circulation of goods and commodities, information and data means that the local is persistently shaped and reshaped by distant influences and agents (Livingstone, 2003, p. 7). As digital technologies continue to play an increasing role in everyday life, Critical GIS combines the technical field of geographic information science (GIS) with heterodox social theory. The result is a rich field whose spatiality in incorporates big data and information science with theoretical approaches in critical geography. A series of critiques of the techno-scientific nature of traditional GIS especially based on actor-network theory as a systematic method of tracing the development of sciences and technologies through socio-spatial processes undergird the formation of critical GIS as a sub-discipline in geography. This dominance of heterogeneous constructivism in sciences and technologal studies acknowledges that geographical phenomena are influenced by a broad range of socio-spatial practices, but, are nevertheless linked to a fundamental reality. Hence, since the development, design, and implementation of science and technology is also social process in everyday life, therefore the scientific and technologic components cannot be isolated from the socio-spatial and socio-political contexts (Sui, 1994; Pickles, 1995; Schuurman, 2000; Cope and Elwood, 2009).

In retrospect, site and situation of science, places of scientific knowledge, spaces of scientific knowledge, spatialising of nature, spatial disparities and interactions of knowledge and educational achievement, and the relations between spaces, knowledge and power are some of the key researches topic related to spatiality. It may argue that the milieus of creativity and innovation, spaces of learning, spatial mobility of knowledge and ideas, knowledge and action, knowledge in organizations, the nexus between knowledge could be considered as another area of interest as far as spatiality issue is concerned. Those mentioned area of interests along with learning and digital technologies and knowledge and economic performance have been the most noticeable issues of geographies of science in the previous three decades. According to Livingstone (2010, p. 4) what animates this line of inquiry is the recognition that very specific kinds of spaces have to be made for the conduct of scientific inquiry.

After this discussion, I tried to provide an analysis of the "new" condition of geographies of science and examine how the spatial causalities operate. Therefore, the main next issue will be that, given such achievements, how we can put spatial causalities first in scientific knowledge in a new era of virtual globalization and what are the main challenges in the dominance of geographic algorithms. I hope to clarify a new position in this debate.

4. PUTTING SPATIAL CAUSALITIES FIRST IN SCIENTIFIC KNOWLEDGE

From the point of view of geographies of science, scientific knowledge is not just the product of specific, individual and bounded sites, places, spaces, and regions that typically reflect the deterministic role of places and regions, "areal differentiation" approach in the history of geography, or which Agnew (1999) called "territorial trap" (which is entered into when it is assumed that all actors within a culturally defined area behave in a similar way or follow the same norms). Indeed, these approaches imply a static account of the geography of science which may miss the other spatial aspects such as what Finnegan (2008) describes as "science in motion".

It is also produced through conjunctures of multitude of hybrid, relational and mobile spatial networks. We need to reimagine production and innovation in scientific knowledge in terms of the encounter of multiple relationships (new knowledge encounters). Rather than

assuming that knowledge enters from the outside to sites or region and diffusion from the inside to the other sites and regions, today we must see knowledge and scientific activity in terms of hybrid and relational spatial networks in a world of contingency and constant becoming. As Driver (1994, p. 388) says, "a focus on the geography of science thus implies more than an acknowledgement of the locational context of science".

New ideas emerge from socio-spatial practices which are always undertaken in particular spatialities. As Haraway (1991) argues, scientific inquiry is not the view from nowhere, but the view from somewhere. Different spatialities present distinct opportunities for producing knowledge and scientific innovations. They set off different socio-spatial processes (such as innovative milieus, networks, and clusters), induce different questions and answers, and foster different experiments and engagements. The processes to attaining new knowledge are highly spatial dependent (Storper and Venables, 2004). For Longworth (2006, p. 7) the concepts of the 'learning city', 'the learning region', and 'the learning community' are geographical models within the social concept of the 'learning society'.

Creativity hardly develops in the placeless realm (Relph, 1976) and the ubiquitous familiarity of non-places (Augé, 1995). Combinatorial creativity in science requires a rich store of knowledge and the ability to form links between many different types of knowledge. However, spatialities offer different prospects and risks of learning based upon different traditional cultural and ideological views in the society; that is the acceptance and rejection of scientific results depend, to a large degree, on where they were produced. For Amin and Cohendet (2004, p. 86), the powers of context -spatial and temporal- should be placed at the center of any theorization of knowledge formation. Furthermore, Bathelt and Henn (2014) emphasized the need for combining local/regional with national/international perspectives on knowledge flows.

Scientific knowledge cannot be regarded independently from the socio-spatial processes through which it is produced. Producers of scientific knowledge are not actors in the placeless world (and describing placeless as the character of scientific rationality), but they are real persons with particular kinds of bodies, histories, and interests that make a difference to the kind of knowledge produced (Barnes, 2004). Today, the role of face-to- face contact on fostering human capital and making innovative ideas or knowledge creation via socio-spatial interactions in terms of learning economies, learning regions, learning cities and learning community have been seen as the most important sources and the driving forces of economic development. Therefore, socio-spatial interactions should be viewed as the variety of ways in which scientific knowledge can be produced and circulated (Florida, 1995; Longworth, 2007).

As Soja (2010) argued, the basic idea is to put spatial (cities) causality at first place. He illustrates this idea more with regard to *The Economy of Cities*, written by Jane Jacobs in 1969. Jacobs defined the city as a settlement that consistently generates its economic growth from its own localized resources. This "spark of city economic life", as she called it, clearly revolves around the stimulus and social savings that arise from dwelling together in cities rather than in rural areas. Density and cultural heterogeneity are its primary triggers. Cities are the concentration of needs, creating many challenges to social reproduction but at the same time, providing greater incentives to address problems in new ways. Cities attract newcomers of all sorts - strangers, visitors, and migrants, who often carry with them innovative ideas. she concludes that "without cities, we would all be poor". In other words, we would still be hunters and gatherers (Soja, 2010, p. 276). This also means that the development of the innovative knowledge and ideas took place not only in the spatial contexts but rather it occurs due to the spatial causalities; that is cities. "The city … has long been recognized as the birthplace of innovation and creativity" (Camagni, 2011, p. 183), because "cities speed innovation by connecting their smart inhabitants to each other" (Glaeser, 2011, p. 7)

From relational view of space, processes do not occur in space but rather they define their own spatial frame. We must therefore focus on the relationality of space-time rather than on space in isolation. Any event which occurs at a point in space cannot be understood by appealing to what exists at that particular point. That means it depends on everything else

going on around it (Harvey, 2006). Massey (2005) believes that we are constantly making and re-making the time-spaces through which we make our lives. That is, space is the sphere in which distinct trajectories coexist; without space we wouldn't have no multiplicity and without multiplicity there is no space. Massey (2005) argued that place is the locus of complex intersections and outcomes of power geometries that operate across many spatial scales from local to the global. Places are thus constituted from multiple, intersecting social, political, and economic relations, which give rise to the myriad interlinkages and interdependencies among places. Places are relational and contingent entities which differently experienced and understood by different people. They are multiple, contested, fluid, and uncertain rather than fixed territorial units. She (1994) emphasizes that one of the key tasks ahead of us as geographers is to forge a 'global sense of place', a map of meaning that takes interconnectedness rather than separatism, routes rather than roots, as its foundation.

Taking into consideration the above argument, two issues seem to be critical with respect to historical/social accounts which are sensitive to the geographies of scientific knowledge. The first, as discussed above, is the question of "spatial causalities". It follows by the need to pay attention to spatialities at a variety of scales. It is necessary to recognize the potential and actual role of spatial scales with regard to size, level, and relation (Howitt, 1998) that critically affect the type of observed and produced scientific knowledge and overall success in science (Kosmidis and Lambrinos, 2018). It is argued that scientific knowledge that appears at one spatial scale of size, level and relation, may be lost at another size, level, and relation. Each spatial scale enables distinctive insights, assumptions, and interpretations which hardly hold true on another scale. Different scales put forward different research questions and may call for different theoretical approaches. From this perspective, spatial scales of various sizes, levels, and relations may function as intermediaries and actants.

Finally, it concluded that the development of innovative knowledge and ideas takes place not only in the spatial contexts but also due to the spatial causalities associated with the myriad interlinkages and interdependencies among places and operates across many spatial scales from body to the planet. "The relational approach suggests it is crucial to study and manage the social interactions and their contingencies that are fundamental to knowledge and innovation" (Faulconbridge, 2017, p. 676). Hence, we must seek knowledge in spatial encounters and betweenness of places, not merely within places. Conjunctures of the multitude of hybrid, relational and mobile spatial networks are the laboratories of the studies of geographers of science and historians of geography in the twenty-first century.

5. HACKING SPATIAL CAUSALITIES IN THE GEOGRAPHIC ALGORITHMS

Although much has been noted and written on the rise of the information age and network society (Castells, 2000; Webster, 2014), telecommunications and the city (Graham, and Marvin, 1996), social and political impacts of geographic information technologies (Elwood, 2000), cities in actor-network relations (Amin and Thrift, 2002), big data (Kitchin, 2013), data revolution (Kitchin, 2014), and code/space (Kitchin and Dodge, 2014) but, there has been little reflection on the spatial causalities of such issues and what we can learn out of them. When we are in the multitude of hybrid, relational and mobile spatial networks, this could be primitive stage of a transform in which the transfer the terrestrial spatial causalities to the virtual spatial causalities. In other words, the use of spatial intelligent and digital technologies have led us to delegate our spatial capabilities to algorithms, due to this fact that they are capable of monitoring, saving and processing huge amount of data and information compering with human agent. The assumption is human spatial capabilities with respect to terrestrial spaces are being transferred to spatial algorithms in the virtual spaces. In a succinct phrase, spatial causalities of geography will become what we can call "spatial causality of algorithms"; though, we are still in the primitive stages of this transformation.

The history of dealing with the dark side of technology and the formation of totalitarian monitoring systems goes back to dystopian perspectives in science fiction novels were written

by Huxley (1932) and Orwell (1949), which are especially popular today with proponents of actor-network theory such as Latour (1987); Haraway (1991); Mitchell, (1995) and more recently also by the historian Harari (2014; 2016). However, one of the most important properties of the geographic algorithms is the irrelevance of people to the physical places and spaces as opposed to the relevance of people in virtual places and spaces. Hence, the major challenges in the geographic algorithms will be need to understand virtual causalities in the spatial algorithms. The following are the list of couple questions with respect to studying geographic algorithms; what geographical rules govern cyberspace causalities? How much do we know about them? Are we being influenced by them or do we influence them? And finally, how can we solve our individual and collective problems in such geographies?

In the twenty-first century, the fact that computers can process human spatial behaviours better than humans themselves could potentially be a threat to humans. Hence, the questions including “data processing by whom, for whom and for what?” would be the most concern in critical thinking. The challenges that Bio-Tech and Info-Tech pose to humans are far greater than the challenges that steam engines, railways, and electricity posed to humans in the twentieth century. Combining the power of Bio-Tech in genetics, brains, emotions, and human behaviour with the power of Info-Tech in unprecedented data processing will lead to formation of big-data algorithms which can most likely take away authority from humans and transfer it to algorithms. In this situation, we will enter the age of algorithm primacy or dominance. As Haraway (1991) has said about the cyborgs (as a primitive form of this phenomena), in the age of algorithm dominance, we are all hybrid identities which connected to sensory receptors and digital technologies, and therefore all of the body's biological processes, spatial mobility, preferences, and patterns which can be stored and processed. In other words, when a person is surfing on the earth (with digital equipment attached to him) or in cyberspace networks, data or information about him is being stored moment by moment. Unlike Geo-graphy, Algorithmo-graphy is not passive and blind, it is constantly monitoring our mobility and behavioural patterns, which we are often unaware of it.

These types of hacking spatial capabilities, decisions, and behaviours of humans will increase dependency and reliance on spatial algorithms. This is because that they have more and better information and knowledge about the spatial features of our lives in terrestrial and virtual spaces than we do. It is so important to note that there are increasingly digital systems that decide on many of our demands based on the information. In addition, unlike the struggles of political geography over the “land” in the pre-modern period and over the “means of production and the centers of production and consumption” in the (post)modern period, the political struggles in political geography will be over the “data flows”. Furthermore, unlike two corresponding symbols that are land and factories associated with pre-modern and post-modern respectively, we do not have much ability to delimit the territorials and properties of information and data. As we may recall, the geographies of the first-original nature were governed by the law of natural selection, the geographies of the second-human-built nature were governed by the law of utility. My final argument is that there are the geographies of the third-virtual nature which are governed by the law of intelligent design. Although we are in the primitive stages of such a development, nevertheless, we are entering the age of the geographic algorithms.

However, the dark side of the age of algorithms may have the light side (before it becomes too late). The ongoing innovations of Bio-Tech and Info-Tech, Informational technology, and relational networks give us opportunities that we haven’t had before. These capabilities have made the world smaller, more open, and more visible via time-space compression. These situations in turn could change our opportunities in which provide more learning and communicating capabilities. Time-space compression makes everyone accessible. It also increases the number of minds which can bring in to work together not only on the common issues and problems but also on common dreams of humankind. Today most human problems take place on a global scale and possessed global aspects which need to have global consensus in order to be resolved. Global relations and consensus can promote

the rate of potential new ideas and innovations. So, we are facing some smart people in which they are not completely delivered all of their spatial capabilities to the algorithms. From a smart people's perspective, technology could be disposal up to a certain point that helps them to control and increase their capabilities and have a better life. So, compromising between the proper balance of the algorithmic and humanistic sides is highly recommended. We have to use information technology and relational networks for making the earth a better living place for all of us.

Information and communication technologies (ICT), Bio-Tech and Info-Tech, Big data, RS, GPS, and GIS, like societal processes of any sort, can only be tools to development, not ends in themselves. They do not operate in a social or ethical vacuum and in moral terms no technology is either right or wrong in itself. A technology's degree of rightness will depend on whose interest it best serves. The correct question to ask was not "are these technologies right?" but "who are they right for, and why? Without considering how to better involve smart citizens in smart spaces, smart technologies become increasingly problematic in the foreseeable future. In the path of the new initiatives that we can undertake there are ample virtual and physical spaces for creativity, innovation, and learning in scientific knowledge.

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