Turning to ontology in STS? Turning to STS through 'ontology'

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Abstract

We examine the evidence for the claim of an 'ontological turn' in STS. Despite an increase in references to 'ontology' in STS since 1989, we show that there has not so much been an ontological turn as multiple discussions deploying the language of ontology, consisting of many small movements that have changed the landscape within STS and beyond. These movements do not point to a shared STS-wide understanding of ontology, although it can be seen that they do open up STS to neighbouring disciplines. Three main thematic complexes are identified in this literature: constructivism and realism; instruments and classification; and the social sciences and the humanities. The introduction of ontology into the long-running constructivism-realism debate can be considered as an acknowledgement on both sides that objects are real (i.e. pre-existing the situation) and constructed at the same time. The second thematic complex focuses on the role of instruments and classification in establishing not only relations of heterogeneity but also of stability. The third thematic complex broadens the debate and actively seeks to promote an STS-driven ontological turn for research

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concerned with the humanities and the social sciences more generally. This study is based on both quantitative and qualitative interpretations of the literature.

Keywords

ontology, science and technology studies, bibliometrics, philosophy, constructivism, realism, classification

Ontology, the study of the general kinds of being/s as such (as distinguished from the study of how we know being/s), has long been a core topic for philosophers. In the Introduction to this special issue, Woolgar et al. open the question of how discussions about an 'ontological turn' within science and technology studies (STS) have challenged the field. Woolgar and his colleagues make a distinction between the study of ontology in a philosophical sense and the STS emphasis on analysing ontology as an empirical phenomenon. In STS, this usually means ontologies in the plural, and accordingly the focus of analysis is on the always fluid and unstable processes by which ontologies come into being (Law, 1996; Mol, 1999, 2002). Multiple and emergent ontologies are already well-known in philosophy (Latour, 1988: 153ff.; Leibniz, [1714] 1898; Quine 1969), but Woolgar et al. also emphasize a distinction between philosophy's theoretical reflections and STS's empirical analyses.

In this article, we address this question by delineating empirically the extent and contours of an 'ontological turn' in terms of relevant discourses. We do so by systematically evaluating the literature published between 1989 and 2008, combining a quantitative, bibliometric analysis with a qualitative reading of this literature. For the quantitative analysis, we first assess the empirical claim of an increase in the use of 'ontology' in the literature, in social science and humanities journals overall, and in a

subset of selected STS journals. We then use more advanced bibliometric tools to analyze which network structures in the social and knowledge relationships in this latter subset of literature can be found. Our results suggest that while there has been greater use of the term 'ontology', this cannot be considered as a single turn but rather as many incremental movements. We explore this further through close reading of the interdisciplinary subset of literature from STS journals, on the basis of which we distinguish three thematic complexes: (a) constructivism and realism; (b) instruments and classification; and (c) social sciences and humanities. In the Conclusion, we draw upon the qualitative and quantitative analyses in order to address questions about the implications for the practice of STS.

We are not seeking here to offer a definitive account of what 'ontology' means in STS. Our objective is twofold: we provide empirical grounding for the claims about the existence of an ontological turn, and we disentangle the range of purposes to which an ontological vocabulary has been put between 1989 and 2008. Although we observe a growing use of an ontological vocabulary in STS, this does not, in our view, emerge as a unified, clear-cut 'turn.' We argue that the word 'ontology' is embedded in three thematic complexes, that overlap both in terms of content and chronologically. The first relates to long-standing debates on realism and constructivism. The second focuses on the role of instruments and classification to establish relations of heterogeneity and stability. The third moves the focus from science, technology, engineering and medicine (STEM) disciplines to the social sciences and the humanities. Furthermore, we can see that 'ontology' is sometimes used as shorthand to re-assert the long-standing commitment to situatedness in empirical research methods, and as a signifier for the centrality of objects in constituting socio-technical relations. From the bibliometric analysis we observe that authors from related fields are making considerable use of core authors in

the STS literature: there is evidence of a turn in other fields towards notions of ontology specified by STS scholars.

Quantitative investigation of the 'turn'

The 'Ontological Turn' in the Social Sciences and Humanities

Among the social sciences and the humanities, STS is not the only discipline in which the status of ontology has been debated in recent years. A search of the Web of Science using 'topic search' for the 20-year period 1989-2008 yielded 5583 documents, including articles and review essays, which contain 'ontology' or some variant.[1] In Figure 1 it can be seen that this use of 'ontology' has increased by more than 770%. During the same period, the *Social Science Citation Index* (SSCI) and the *Arts & Humanities Citation Index* (A&HCI) together increased by only 40% from 214,412 to 299,638 documents.

< *Figure 1: The ontological explosion – about here* >

Before deciding whether this dramatic increase in the literature constitutes 'a turn towards ontology,' it is important to examine this data more closely, paying particular attention to the dynamics in different disciplines. To facilitate presentation, one can group cognate fields using the 'Web-of-Science Categories'.[2] 'Philosophy', 'ethics' and 'religion' are listed separately but, as would be expected, account for three of the top five disciplines using 'ontology' (38% of the total between 1989-2008). The increase has been steady, from 44 documents in 1989 to 179 in 2008, but still less dramatic than for the social sciences and the humanities overall. Both psychology-related disciplines (12% of total) and the computer and information sciences (9% of total) use the term 'ontology' frequently, and the increase is startling in both these areas. Both had fewer than 10

documents using ‘ontology’ at the beginning of the period, but 50 or more annually since 2003.[3]

< Figure 2. Publications by Subject Category – about here >

As Figure 2 shows, the category ‘other’ accounts for 11% of the total, but this includes all of the humanities except philosophy, as well as many social science disciplines. Other Web-of-Science Categories where ontology has emerged as an important topic are sociology (including social issues and interdisciplinary social science), geography (including urban studies, area studies, physical geography, environmental studies, ecology and environmental engineering), and management studies (including business, operations research and management science, public administration and business finance). In these areas, the increase has also been dramatic, with fewer than five publications per year using the word ‘ontology’ at the beginning of the period, and none at all in some years, to more than 30 per year for geography and management studies, and more than 50 per year for sociology after 2005.

Most STS journals are included in the Web-of-Science Category ‘History and Philosophy of Science’ (HPS; 6.1% of the total number in Figure 2). HPS also has demonstrated a steady increase, with very small numbers of publications in 1989-1991, in the teens for the years from 1992-2000, and in the 20s and 30s since 2001. However, the classification of STS journals is not straightforward, and we present an alternative way of identifying relevant journals below.

Turning to Ontology in STS

Let us now focus on the possible 'turn towards ontology' in STS more specifically. In attempting to trace the use of 'ontology' in STS, the questions to be addressed are how to define STS and which journals to include. While useful for the above analysis, the Web of Science classification is machine-generated, is known to contain considerable flaws (Rafols and Leydesdorff, 2009), and is not sufficiently fine-grained for our purpose.

For a more detailed analysis, it would make more sense to use one of the STS community's own self-definitions. We considered the STS Handbooks (Jasanoff, *et al.*, 1995; Hackett, *et al.*, 2008), but they did not contain sufficient references to 'ontology' and its derivatives.[4] As a starting point for the identification of core STS journals the website of the largest international professional association for STS, namely the Society for Social Studies of Science (4S), provided a useful alternative.[5] Sixty-eight journals are listed, of which 26 are not included in the Web of Science. The other 42 journals are distributed over a wide range of Subject Categories, reflecting the multidisciplinary nature of STS. However, only 20 of these 42 journals contain documents that mention 'ontology' (or some variant, see note 1) amongst their topics, resulting in a set of 131 documents, broken down in Table 1.

< *Table 1. Number of articles using 'ontology' in STS journals – about here* >

This set of 131 documents was our starting point for both the qualitative and quantitative analyses. The fact that not all journals included on the 4S website address ontological debates already indicates that if an ontological turn in STS has taken place at all, then this turn may be limited to specific subfields of STS and does not necessarily

encompass STS as a whole. The data presented in the remainder of this article offer support for this expectation.

Figure 3 shows the distribution of the 131 articles in our sample by publication year. The growth over time follows a pattern significantly similar to 'ontology' at the level of the Web of Science database as a whole (see Figure 1; the rank-order correlation ρ = 0.742; $p < 0.01$), although this may deviate for specific years (e.g., a dip in 2006).

< Figure 3. Ontology in STS articles, 1989-2008 – about here >

This first bibliometric description of the literature indicates that there has been an increase in the discourse about ontology. In the next section, we conduct more elaborate bibliometric analyses in order to examine social and knowledge-base networks amongst the set of 131 documents from the STS journals. This provides some pointers for the qualitative review of these documents. In the subsequent section, we discuss three substantive themes that emerge from our reading of this literature.

Co-author, Co-word and Citation Analysis

Because of actor-network theory's (ANT) emphasis on semiosis, there are affinities between it and scientometric approaches. Thus, in the 1980s the question arose whether ANT's ontology could be captured using co-word analysis (Callon et al., 1983; 1986; Leydesdorff, 2010). Special computer programs such as Leximappe and Candide were developed, but the research programme of scientometrics rapidly became more complex and formalized, and increasingly alienated from the qualitative tradition. 'Mapping the dynamics of science', however, did not prove to be a *sine cure*. It entailed both problems of how to decompose the complexity at each moment of time—for example, issues of using various clustering algorithms—and problems about time-series

analysis. While the constructivist tradition in STS is interested in diachronic, historical explanations, maps of science tend to focus on structural properties and relations at specific moments in time.

With the availability of ever cheaper and more powerful computers and the internet, as well as enhanced possibilities for visualisation developed in network analysis, scientometricians have developed a number of standardized practices for drawing semantic maps from texts (for example, Leydesdorff and Hellsten, 2005), analysing social networks among agents (Otte and Rousseau, 2002; De Nooy et al., 2005), and using cited references for historiography (Garfield et al., 2003). An advantage of the scientometric approach is that large numbers of documents can be addressed that one could not read individually and/or code manually. Variation in the data and possible dissemination patterns can nonetheless be brought to the fore by a more structuralist approach (Kranakis and Leydesdorff, 1989).

Using the same 131 documents already identified, we pursued three types of bibliometric analysis, which we subsequently also combined: (1) co-authorship relations as indicators of the social network formation (Price, 1963; Schott, 1991; Wagner and Leydesdorff, 2005), (2) bibliographic coupling in terms of shared references that may indicate a common knowledge base (Kessler, 1963; Small, 1978), and (3) co-word analysis for the construction of semantic maps (Callon et al., 1983).

Results: Networks of Authors, Words and References

The 131 documents in our set are predominantly single-authored. Only 37 were co-authored, and the ensemble of dyads and triads of co-authorship relations do not add up to a coherent network despite the long period under study. Among the eleven authors with more than a single contribution to the set, only Ogborn forms a network beyond a dyad, in the field of science education (Mariani and Ogborn, 1991, 1995; Martins and

Ogborn, 1997; Ogborn and Martins, 1996). This result suggests that our set of documents is not carried by a tightly knit scientific community.

Bibliographic coupling was performed using the set of 6055 references cited in the 131 documents. In general, two documents are considered to be bibliographically coupled if they are co-cited in the same citing document (Kessler, 1963; cf. Small, 1978). Bibliographic coupling can thus show the knowledge base of publications in terms of the structure among the references in the set. However, this analysis did not provide a coherent network. Different authors cite different literatures; and the collection of documents is highly interdisciplinary in terms of the journals and books referenced. Even though the original set comes from a list of journals identified as relevant to STS by 4S, the results of the bibliographic coupling suggest that the field is fragmented.

The results from both the co-authorship analysis and the bibliographic coupling provide further support for the expectation articulated earlier, based on our initial scanning of the 42 STS journals included in the Web of Science: if an ontological turn in STS has taken place, it is limited to specific sections of STS and does not cover STS as a whole.

Our next step was to examine title words. The 131 titles contained 607 non-trivial title words, which occurred a total of 958 times. Fifty-five of these title words occurred more than twice. This allowed us to draw a semantic map among them (Figure 4). Following the standard practice of scientometrics, we used the cosine for the normalisation (cosine > 0.25; see Ahlgren et al., 2003).[6] The map positions 'ontology' on the right side with a special relation to 'science' (these two words occur most frequently, namely 21 times) and relates the larger network to a specific network consisting of the words 'historical' 'material' from the 'eighteenth' 'century'. This 'historical ontology' approach with its focus on 'ontological shifts' (Klein, 2005) is discussed below when we describe the second thematic complex.

< Figure 4. Co-word map among 55 title words – about here >

Several authors use 'ontological' as an adjective rather than 'ontology' as a noun. The adjective, however, is embedded in another semantic cluster among words such as 'perspective' and 'epistemological'. A dense cluster is found on the right side of Figure 4, representing a normative tradition in education research that focuses on 'promoting conceptual change' in 'learning.' On the left side, themes from science education, public understanding of science, and STS seem to be intertwined.[7]

Following Callon et al.'s (1986) call to map heterogeneous networks, we combined the co-word map (of 55 co-words) with (1) the network of eleven authors who published more than once and (2) the eight journals that contain the top-1% of the cited references in these publications (cf. De Nooy and Leydesdorff, 2009). Despite the added variables, the co-word map presented in Figure 4 largely retains its structure in the derived map (not shown here, but available as Figure 4a at http://www.leydesdorff.net/ontology).[8] A number of science education journals form a dense cluster, and *Social Studies of Science* is positioned at a distance from this cluster. Further (factor) analysis of the underlying matrix shows that the journal *Social Studies of Science* and the title words 'issue', 'critique' and 'public' form a specific component of this network.[9]

Our analysis so far suggests that STS does not enjoy a strong position in this broader intellectual field and therefore we tried another representation. Instead of using the names of journals, we developed a new routine to enable us to use the authors cited and co-cited in our sample of 131 documents.[10] Figure 5 shows the co-occurrence network of the 96 top-cited authors in these 131 documents. In our opinion, this figure illustrates the importance of the STS community as a knowledge resource to the field.

< Figure 5. Top 0.2% cited authors – about here >

This result may not be surprising given our initial selection of the literature. However, the structural components of this network were unexpected. Factor analysis indicates that there is a central group contributing to this literature, including the following authors (in descending order): Bruno Latour, Michel Callon, Steve Woolgar, Susan Leigh Star, Harry Collins, Michel Serres, Annemarie Mol, Michael Lynch, Donna Haraway, Lucy Suchman, Karin Knorr Cetina, David Bloor, Barry Smith, Brian Wynne, John Law, Geoffrey Bowker, Andrew Pickering, Michel Foucault, Hans-Jörg Rheinberger, Jean Lave, Alan Irwin, Wolff-Michael Roth, Ulrich Beck, Anthony Giddens, Jacques Derrida, Peter Galison, Jay Lemke, Ian Hacking, Simon Schaffer, and Karl Popper. Furthermore, the pattern of citations to Latour, Galison, Hacking, and Schaffer is negatively correlated to that of authors in science education and education research.

By combining these 96 most-*cited* authors with the 55 most frequently occurring title words in the *citing* documents one can generate another heterogeneous map (Figure 6). Unlike the education researchers, the STS contributions are scattered across the field. The philosophers are positioned in specific corners, and a group of scholars discussing evolution theory (Richard Dawkins, E.O. Wilson) is related to historical ontology and Marxist theory. The contributions of STS authors, however, function as a latent dimension next to, but different from the philosophers and the education researchers, and they prevail in this map (see at http://www.leydesdorff.net/ontology for a colored version of this map).

< Figure 6. Heterogeneous map of 96 most-cited authors and 55 title words–about here>

In summary, we could not find intellectual or social coherence in the interdisciplinary set using traditional scientometric instruments of co-word and co-author analysis. However, the STS community was found to exert a strong influence when analyzing the cited authors. These authors and their *œuvres*[11] are used as a knowledge base and recognized as an intellectual programme by the authors in neighbouring fields publishing in this same set. The programs of radical constructivism, ANT, and the socio-cognitive reconstruction of ontologies resound in these otherwise unrelated literatures as part of their knowledge base.

Three Thematic Complexes

The scientometric analysis presented above suggests a number of conceptual areas requiring further attention. In order to elicit these distinctions, we read the 131 documents referring to ontology. Based on this reading, we identified three thematic complexes, that appear to represent a three-part chronological development in discussions about ontology: (1) from the invocation of 'ontology' in debates on realism and constructivism to (2) a concern with the role of instruments and classification in establishing relations of heterogeneity and stability to (3) the broadening of debates on ontology beyond the STEM disciplines to include the social sciences and the humanities. Within each theme various micro-shifts in the discourse about ontology can be identified. In line with the bibliometric analysis, we see that these shifts do not add up to one larger 'ontological turn' in STS, but reflect a number of longer-standing concerns within the literature. We want to stress that our temporal demarcation is not clear-cut as themes overlap and co-exist.

The identification of these three thematic complexes is based on an intellectual reconstruction informed by our knowledge of STS as well as by the insights generated by the quantitative analysis. Although this perhaps creates a different kind of order to the

debate(s) on ontology in STS than might be recognized by the authors involved, we do so for the purpose of a coherent presentation and our discussion of the ontological turn.

Constructivism and Realism

The constructivism–realism debate of the 1980s and early 1990s is an obligatory passage point for understanding the discourse about ontology in STS, and this returns in more recent debates using the language of ontology. This is succinctly captured by Landström's review of the edited volume *Actor Network Theory and After* (Law and Hassard, 1999), in which she focuses on Mol's chapter 'Ontological Politics. A Word and Some Questions':

> Mol's notion of ontological politics appears to me both to inherit and to transform the conceptual space opened up in the debate over the (social) construction of reality that preoccupied realists and relativists in S&TS in the 1980s. This debate also concerned who has the power to determine what is real. The territory staked out for ontological politics is marked by the way power is produced and reproduced in the technoscientific performance of realities. (Landström, 2000: 477)

Although Landström did not specify the added value of using an ontological vocabulary instead of a constructivist one, it is important to note that Mol's ontological politics is not the only version available. In his review of the metaphor of construction in STS, Sismondo (1993a: 535) for example adopts a stronger realist line and criticizes some constructivists for conflating ontology with epistemology—the so-called 'epistemic fallacy' critical realists aim to avoid.

In a response, Knorr Cetina rejects Sismondo's analysis and, in defending 'strong constructivism' (1993: 559), elaborates on the relation between construction and ontology. She notes that one of the main characteristics of constructivism is its

acknowledgement of philosophical debates on ontology and epistemology, and the simultaneous reconstruction of these debates while pursuing empirical analysis. This emphasis on empirical research (especially in laboratory studies), according to Knorr Cetina, 'brings into focus the instrumental, symbolic and political work required to furnish the world with new, scientifically derived objects' and 'shows how the world is slowly moulded into shape in ever new ways through successive generations of (scientific) practice' (1993: 559-560). Although Knorr Cetina vehemently rejects realism (without specifying what type of realism she rejects), she does not deny the existence of the world independent of the observer and simultaneously emphasizes that objects pre-exist the practices through which they are changed. At this point, the nominalism-realism divide breaks down.

In our reading, Knorr Cetina's position is not very different from Sismondo's point that some preliminary ontological assumptions are needed concerning the properties of objects in order for research to be possible (1993b: 566). Indeed, as we see below, in her own empirical work Knorr Cetina is a much stronger realist (in the sense of accepting and articulating the role of pre-existent objects and their relations in shaping practices) than many other authors in the STS debate on ontology. A similar negotiation between constructivism and realism is visible in Hacking's entity realism (1999) and his notion of interactive kinds, which are classifications that produce effects on the objects they classify. Objects, from this perspective, are real and constructed at the same time (Powell, 2001: 305).

Instruments and Classification

A second thematic complex within the STS debate on ontology picks up Hacking's focus on classification, and revolves around the role of instrumentation and classification in establishing relations of heterogeneity and stability. Ontological debate in this relatively

differentiated thematic complex is largely refracted through the discussion of particular case studies of the STEM disciplines.

The studies of instruments and technologies used in particular scientific practices range from infertility treatment (Cussins, 1996), neurosurgical practices (Moreira, 2000), neuroinformatics (Beaulieu, 2001), stem cell production (Waldby and Squier, 2003), and human insulin manufacturing (Robins, 2002) to the production of fluoridated water (Sellers, 2004), the classification of plant materials (Klein, 2005), biodiversity (Bowker, 2000), and early medieval geometry (Zaitsev, 1999). Although primarily interested in the empirical particularity of each case, three strands of ontological claims are made by these different authors.

Cussins (1996), in one of the first articles investigating the ontological dimension of a scientific site, coins the notion of 'ontological choreography' to analyze the ways in which patients in infertility clinics are constantly interacting with particular technologies (such as the pelvic exam, ultrasound, diagnostic surgery, lab research on embryos), and how this implies that subjects need to be understood as ontologically heterogeneous. Cussins and many other ANT-inspired analyses emphasize local specificity, emergence, and the fluidity of relations.

A second strand is informed by debates on historical ontology, and tends to operate with longer time scales. This almost necessarily leads to an acknowledgement of the stability of relations and the (partial) layering of newer practices over older ones. Klein, for example, traces a trajectory of ontological shifts from 1700 to 1830 by studying plant materials and the ways chemists ordered and categorized these materials. In doing so, she enriches our understanding concerning the emergence and stabilisation of particular chemistry practices, methods, and plant materials as research objects over many decades, leading to an understanding of 'historical transformations of chemistry on a broader cultural scale' (2005: 273).

A third strand within this thematic complex draws attention to the role of classifications and concepts in the production of new scientific objects. This concern is already visible in the work discussed above, but is central to Daston's research on scientific observation (2008). Daston is interested in 'the ontology of scientific observation: how expert observation discerns and stabilizes scientific objects for a community of researchers' (2008: 98). She is particularly interested in the tacit skills and accumulated experience necessary to be able to observe in highly specialized disciplines (see also Iliffe, 2004).

Research in science education on conceptual change and the position of learners covers similar terrain, but remains almost completely separate from these debates, as we saw in the bibliometric analysis. Kelly (1997) compares radical constructivism with conceptual change theory and argues that the latter is not only a normative theory, in the sense that it 'concerns itself with identifying what counts as good reasons for theory change or choice' (1997: 358), it is also indifferent towards particular ontological commitments. This 'ontological impartiality' (1997: 360) is seen to enable researchers with differing metaphysical positions to participate in the same research programme. Conceptual change theory, in other words, simply ignores or at the very least downplays the relevance of the STS constructivism-realism debate for actual empirical research.

Indeed, what is most striking in the empirical applications of conceptual change theory is not its ontological reflexivity, but the normative nature of the analysis. Lee and Law (2001) highlight how researchers in science education have become concerned with the fact that students have already acquired considerable knowledge about the world prior to formal education. The problem is then defined as 'how to bring about conceptual change in learners' (2001: 111). The 'ontological re-categorization' (2001: 112) this is seen to involve acknowledges the need for teachers to build on students'

prior conceptions, but the ultimate goal is to initiate these students into the concepts, theories, and explanatory ideals of science (see also Venville, 2004; Kang, 2007).

STS and Ontology beyond the STEM Disciplines

The third theme we have identified is less prominent than the first two but it did emerge from the bibliometric analysis. It broadens the topic of ontology from a concern with instrumentation and classification in the STEM disciplines to the social sciences and the humanities, addressing issues of social ontology. Again, various parallel discourses about ontology can be identified.

At one extreme of the limited connections between the various discourses about ontology, we find the neo-Marxist journal *Science & Society.* This journal neither contributes to the previous two thematic complexes nor to any of the other debates in this third theme, but it is listed by 4S as belonging to the STS community. Contributions to this journal limit the discussion of ontological questions to theoretical debate. For example, describing and defending 'dialectical ontology'—that places the concept of labor at the heart of its explanation—Browne (1990) argues that Lukács uses ontology 'as implying a particular attitude towards reality, consisting of the discovery of "the forms of being that new movements of the complex produce" (Pinkus, 1975: 21)'. Lukács's argument, according to Browne, 'reveals the necessary constant interpenetration between consciousness and being, between theory and practice' (1990: 210).

Combining historical ontology with analysis of the role of instruments in the social sciences, Brain (2001) describes Max Weber's rejection of the extension of laboratory tools — the model of the natural sciences — to social problems and his attempt to develop alternative techniques of measurement. In designing a questionnaire and using this in a survey on the conditions and attitudes of industrial workers, Brain argues that Weber implemented a 'method of measurement which captured a different social

ontology, specifically one in which the workers' attitudes and states of mind might be discovered both on the workers' own terms as well as within the contingent historical field in which they operated' (2001: 651).This historically and spatially sensitive approach is also visible in Galison's (1995) theory of 'trading zones', which is used by Huang (2005) to examine how Chinese scientists communicated with and appropriated knowledge from Jesuit scientists in the sixteenth, seventeenth, and eighteenth centuries. Similar to the historical ontology approach, the notion of ontology adopted here covers broader timescales and is influenced by the French *Annales* school.

The shift of the ontological discussion away from a concern with highly complex machineries of instrumentation in research settings to more obviously sociological themes is in danger of producing empirically rather trivial statements. Bruun Jensen and Markussen (2001), for example, adopt an ontological vocabulary in their analysis of a controversy around a church on the northwest coast of Denmark. The goal is:

> to observe the work particular agents do in constructing *ontological* narratives supporting specific versions of reality which would allow the church to stand or fall. The narratives are ontological precisely in the sense that they are not concerned with a level of language or semiotics, as distinguished from materiality. (2001: 797, italics in original).

The empirical analysis that follows draws exclusively on newspaper articles, websites, and policy documents. This seems no different from established forms of textual analysis, as the church is analyzed as it is represented in texts, but the discursive construction of a much more complex object-ness is largely ignored. In our opinion, it remains unclear what the language of ontology adds to this analysis. Furthermore, whereas the argument that the ontological turn directs attention to the role played by scientific practices in shaping and even producing new entities can be said to be innovative, it tends to remain a rather superfluous argument in a more obviously social-

context type of analysis. One would be hard-pressed to find a social scientist who denies that actors produce realities through their practices.

ANT and post-ANT arguments have drawn most attention as propagators of the ontological turn in the social sciences and humanities. Latour (1997) aims to open up the debate on the resources of critique by introducing the notion of 'factish' in order to shortcut the debate between constructivism and realism. The factish 'is what is retrieved from the massacre of facts and fetishes when the actions of their makers are explicitly recovered *for both'* (Latour, 1997: 69). This is seen to reintroduce human agency into the fabrication of facts by emphasizing the existence of multiple 'practical ontologies' (1997: 78). The goal of critique should not be to deconstruct beliefs by showing the underlying facts, but instead '*to keep the diversity* of ontological status against their transformation into facts and fetishes, beliefs and things' (1997: 81, italics in original).

Marres (2007) is rhetorically more modest, but covers similar terrain. In exploring the relation between public controversies around techno-scientific issues and the emergence of democratic politics, she draws on American pragmatism and the work of Gomart and Hennion (1999) to describe the ways actors are implicated in particular issues through 'ontological associations' (Marres, 2007: 774). There are multiple dimensions in her use of ontology, but central to her argument is that the 'socio-ontological approach' of STS undertakes an ontological turn in the conception of democratic practices by explicitly analysing the role of non-human entities in issue formation.

This orientation towards the object-ness of social life is interpreted rather broadly by Marres, who argues that issues should be understood from a socio-ontological perspective as 'being constituted by institutional, physical, monetary and legal ties, among others' (2007: 773). Drawing on Dewey, she also argues that actors organize as a public only when implicated in a problem by which they are affected, which

necessitates the adoption of a 'relational ontology' (2007: 768). Furthermore, she highlights that the particular relevance of STS in studying public involvement is the appreciation of 'multifaceted associations'. The socio-ontological approach, in other words, is above all also a call to attend to complexity. This latter aspect is also reflected in Bruun Jensen's (2004) claim that the constructivism of STS points to shifts away from a representative to a performative idiom, and from an epistemological approach to a practical ontological approach.

Although this ANT representation of the ontological turn in STS tends to be dominant in the STS literature, it is by no means uncontested. In his review of Mol's *The Body Multiple: Ontology in Medical Practice* (2002), Harbers (2005) pursues an established line of criticism towards ANT. He argues that Mol's reluctance to address the question of power and her advocacy of a style of research that concentrates on how worlds practically come into being by following actors around, is subject to 'inherent conservatism', since it can only represent the worlds of these actors. Harbers advocates a much more open form of writing that introduces different styles and traditions of criticism and argumentation irreducible to the positionalities of the actors studied. Mol's position would lead to 'ontological liberalism', since it evades the issue of which practices are to be preferred (2005: 581). Harbers, in other words, links the question of power to a normative critique of ANT.

As mentioned above, these three thematic complexes overlap in content and in time. Nonetheless, our categorisation enables us to understand better how the ontological debates within STS have emerged since the late 1980s. The language of ontology is used to assert long-standing commitments to situated, ethnographic research methods, and to signify the centrality of objects in constituting socio-technical relations. It is also used at different times as a way of revisiting foundational debates between realism and constructivism.

Conclusion

Deploying the notion of 'turn' can be a powerful rhetorical move (Woolgar, 1991; Pinch, 1993). We have simultaneously deconstructed and reconstructed any potential move of a claim to an ontological turn prevailing in STS. Our results suggest that STS itself has not been turned, but the increase of ontological vocabulary has provided an opportunity for the community to re-visit long-standing debates about methods, epistemologies, and research loci. More importantly, we have observed how STS has turned debates about ontology in other fields.

In tracing the modalities and contours of an 'ontological turn' in STS, we have pursued a combined quantitative-qualitative analytical strategy. Such a strategy was more common in STS in the 1970s and 1980s, but qualitative and bibliometric approaches have grown apart to such an extent that the qualitative literature rarely cites the bibliometric literature (Leydesdorff and van den Besselaar, 1997; van den Besselaar, 2001; cf. Bhupatiraju et al, 2012). In this article, we have demonstrated the added value of adopting such a combined strategy, since it has generated knowledge on the ontological turn in STS that could not have been produced by a single approach. The bibliometric analysis suggested lines of enquiry for the qualitative reading, and the qualitative reading informed our interpretation of the figures generated by the bibliometrics. In addition to our conclusions about ontology, we hope that this article encourages a rapprochement and complementarity between the qualitative and quantitative traditions. Combining methods can, in our view, be productive.

Developments in scientometrics (such as co-word analysis, citation analysis, and bibliographic coupling) and in visualisation (used in social network analysis and internet research) have increasingly resulted in standardized tools that can be imported into qualitative research without raising methodological worries (for example, Amsterdamska

and Hiddinga, 2004) because issues of bibliometric quality control are addressed by the information sciences literature. The interacting and aggregating texts can be expected to form semiotic networks that develop dynamics in heterogeneous dimensions that remain only partially visible—and therefore partially latent—to reflexive agents accessing these texts as authors and readers. Paying attention to these networks can only increase our awareness and sensibility of the dynamics of intellectual debate about ontology, or other topics. Recognition of the limitations of bibliometric techniques forces us not only to develop new techniques, but also to pay attention to the original texts.

We showed that the co-authorship relations in this document set did not add up to a coherent network, with the partial exception of the literature on science education, which exhibits limited co-authoring. The co-word analysis made visible a network referring to the historical ontology approach. By combining the different attributes of texts, the heterogeneous map shows the journal *Social Studies of Science* to be positioned at a distance to the science education cluster, while closely related to the words ‘critique’, ‘philosophy’ and ‘issue’. Finally, bibliometric research on the authors cited and co-cited by the set in the 131 documents highlighted the centrality of STS authorship in discussions about ontology.

Although the descriptive statistics suggested that there has been almost an eightfold increase in the use of the word ‘ontology’ in the social sciences and humanities, the more detailed analysis of the STS literature forced us to re-visit our initial expectation about the nature and the extent of the turn. Both the qualitative and the quantitative analysis suggest that the so-called turn is fragmented, even though STS authors and the journal *Social Studies of Science* have played a pivotal role in contemporary discussions about ontology. Our results suggest that the construction of a semiotic platform about ontology in STS has, in important respects, provided a vehicle for the dissemination of the work of STS authors into neighbouring disciplines.

More substantively, the bibliometric analysis is consistent with our reading of the literature: we are dealing with parallel and largely disconnected discourses about ontology within the STS literature that each addresses different audiences. These do not (yet) point in the direction of a shared STS-wide understanding of ontology, but instead tend to take place in parallel realms with only limited cross-referencing. With insights gleaned from the bibliometric analysis, our reading of the literature enabled us to fill out three main thematic complexes: constructivism and realism; instruments and classification; and the social sciences and humanities. Each of these can be further divided into smaller networks, which overall leads to a rather fragmented debate on ontology in STS.

First, the introduction of ontology into the long-standing constructivism-realism debate signifies to some extent a rapprochement and an acknowledgement on both sides that objects are both real (i.e. pre-existing the situation) and constructed at the same time. In other words, the programmatic battles of the 1980s have receded in favour of a more self-confident and pragmatic—and empirically oriented—mode of analysis.

The second thematic complex of instruments and classifications has been shaped by the emphasis in ANT on fluidity, emergence and local specificity. At the same time, it is shaped by an approach focused on historical ontology as well as research on scientific observation that is much more sensitive to the stabilization of relations over longer time scales than ANT usually cares to acknowledge. Covering similar terrain, but otherwise isolated within this second thematic complex is a highly normative research programme on conceptual changes in science education.

The third thematic complex broadens the debate and actively seeks to promote an STS-driven ontological turn for social science and humanities research in general. This applies to the theoretical debates in the Marxist niche of *Science & Society*, but

even more so to ANT and post-ANT authors such as Latour, Marres, and Mol, who advocate the use of multiple, relational ontologies in order to enable an awareness of the diversity and complexity of socio-technical environments.

In summary, our empirical investigation of the question of an 'ontological turn' in the relevant STS literature did not provide strong evidence for such a turn. There has been an overall increase in the use of the word 'ontology' in STS and elsewhere; and there have been a number of shifts in the literature, but they cannot be considered as adding up to a single and identifiable turn. The broader conclusions to be drawn from our analysis relate to debates about the politics of reality construction and the politics of (disciplinary) knowledge. First, as we have demonstrated above, debates about ontology can be considered as ways of drawing attention again to the constructed nature of reality. By showing how objects and issues are constructed and categorized, possibilities for interventions and transformation become visible. Not only things, but also ontologies could be otherwise. Second, the increased use of 'ontology' in STS discourse has influenced neighbouring fields more than we had expected. In other words, the discursive shift towards ontology in STS constitutes a successful ‘branding’ strategy, contributing to the enhanced visibility of STS beyond its immediate borders.

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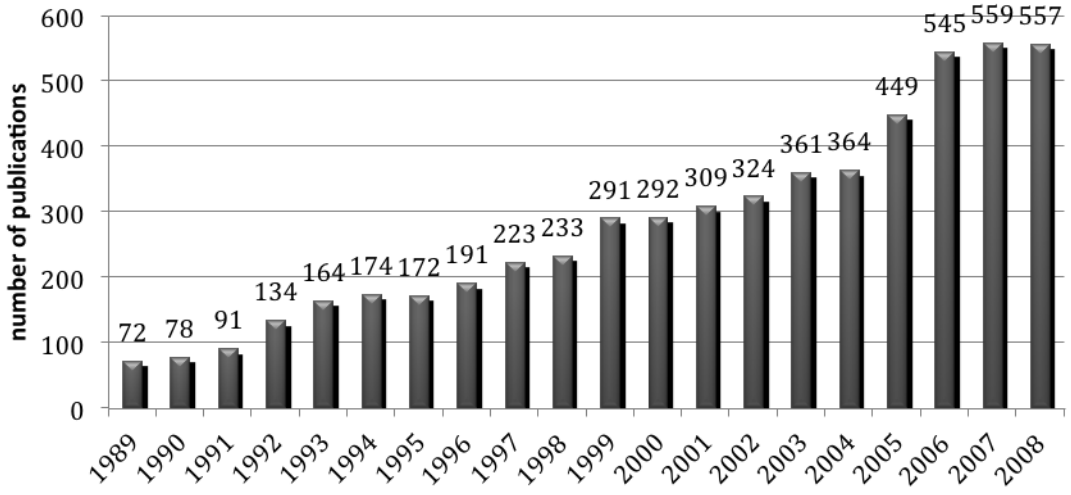
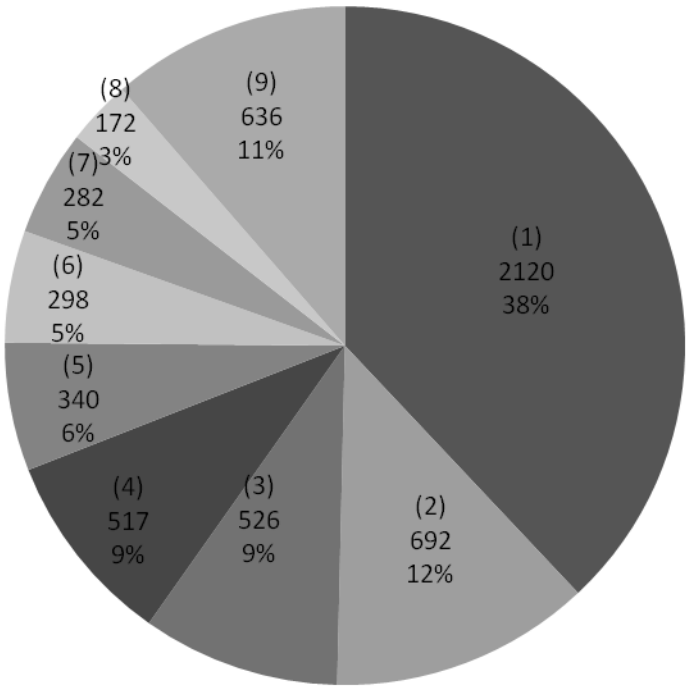


Figure 1: The ontological explosion, 1989-2008



(1) Philosophy, ethics & religion
(2) Psychology
(3) Computer & information science
(4) Sociology
(5) History & philosophy of science
(6) Management & business studies
(7) Geography
(8) Education
(9) Other

Figure 2: Publications by Subject Category, 1989-2008

Table 1. Number of articles using 'ontology' in STS journals.

Studies in History and Philosophy of Science	25
Social Studies of Science	15
International Journal of Science Education	15
Social Science & Medicine	13
Journal of Research in Science Teaching	12
Science Education	9
Isis	8
Science & Society	8
Science in Context	8
Science, Technology & Human Values	5
Configurations: A Journal of Literature, Science, and Technology	2
Interdisciplinary Science Reviews	2
British Journal for the History of Science	2
Annals of Science	1
Osiris	1
Technology and Culture	1
Public Understanding of Science	1
Politics and the Life Sciences	1
Journal of Risk Research	1
Technology in Society	1
TOTAL	131

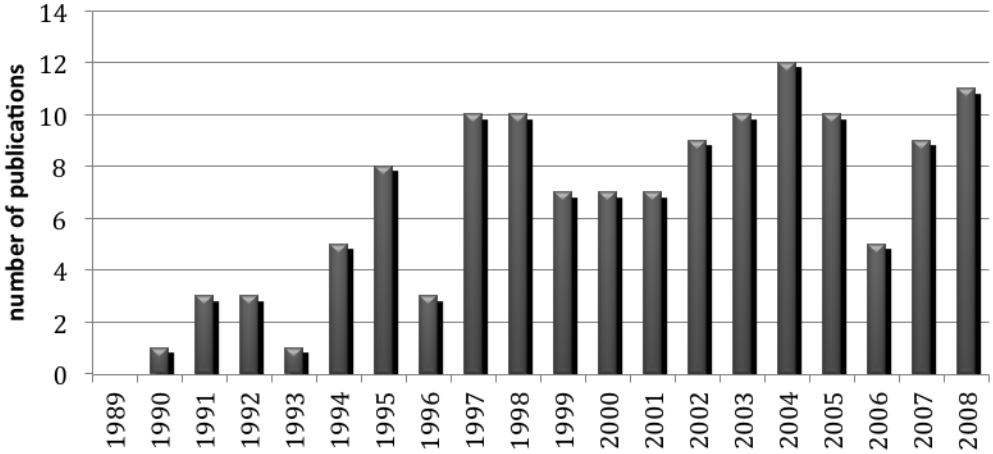


Figure 3: Ontology in 131 STS articles, 1989-2008

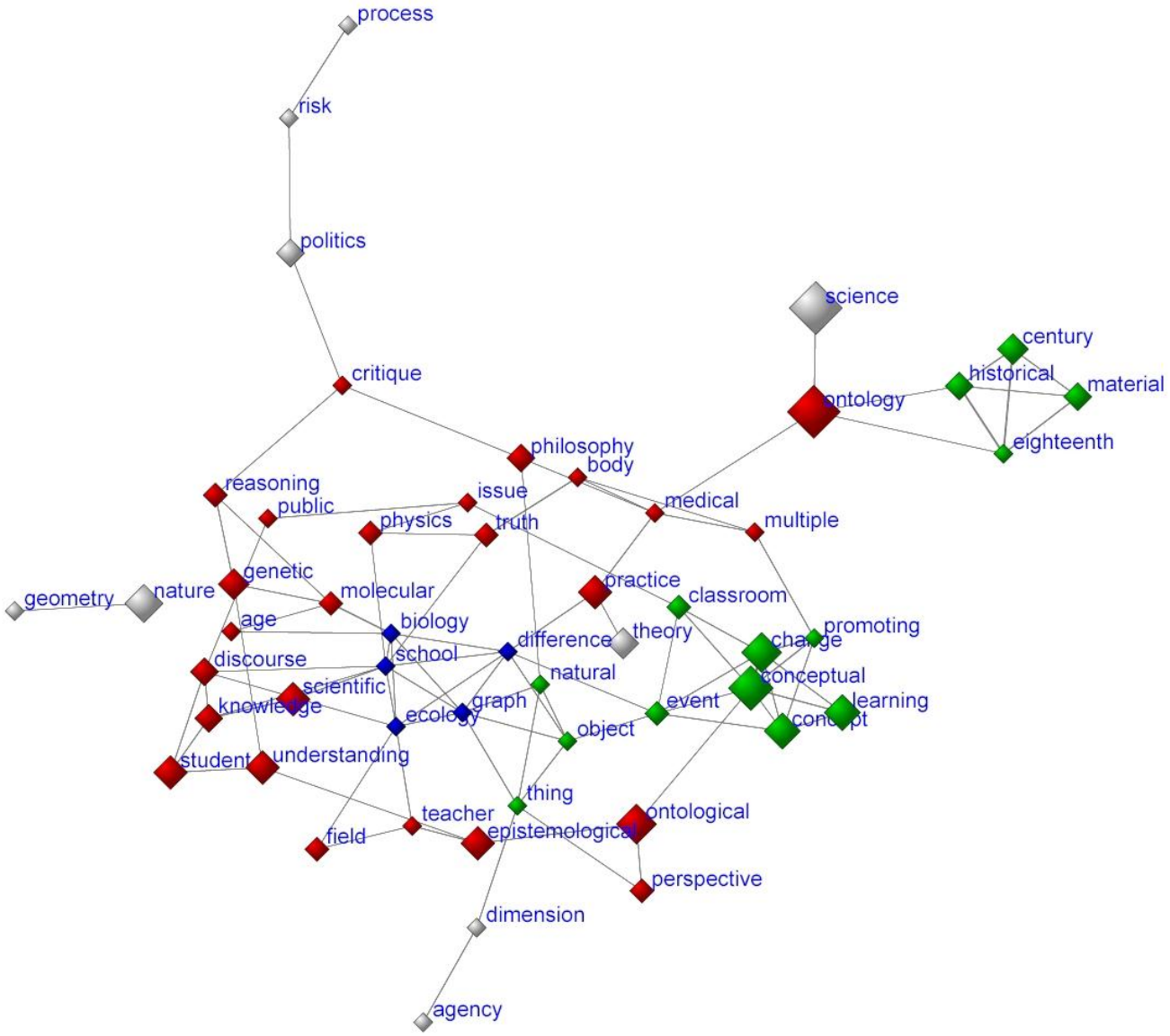


Figure 4: Co-word map among 55 title words related at cosine > 0.25. (Colors were attributed using the *k*-core algorithm in Pajek). A full and colored version of this map can be retrieved at http://www.leydesdorff.net/ontology/figure4.htm.

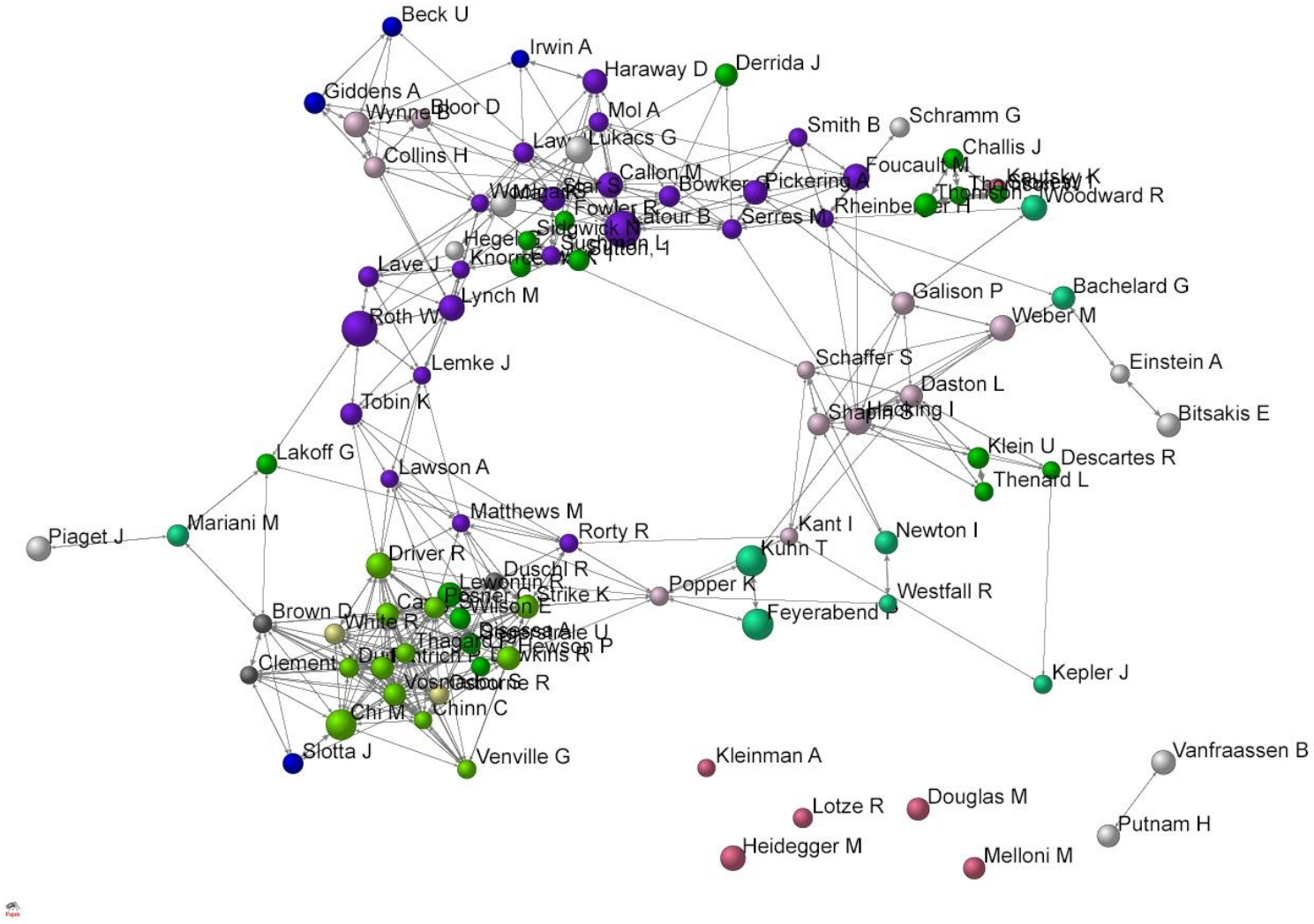


Figure 5: Top-0.2% cited authors in the set of 131 STS documents; cosine > 0.25. (Colors attributed on the basis of the *k*-core algorithm in Pajek.) A full and colored version of this map can be retrieved at http://www.leydesdorff.net/ontology/figure5.htm.

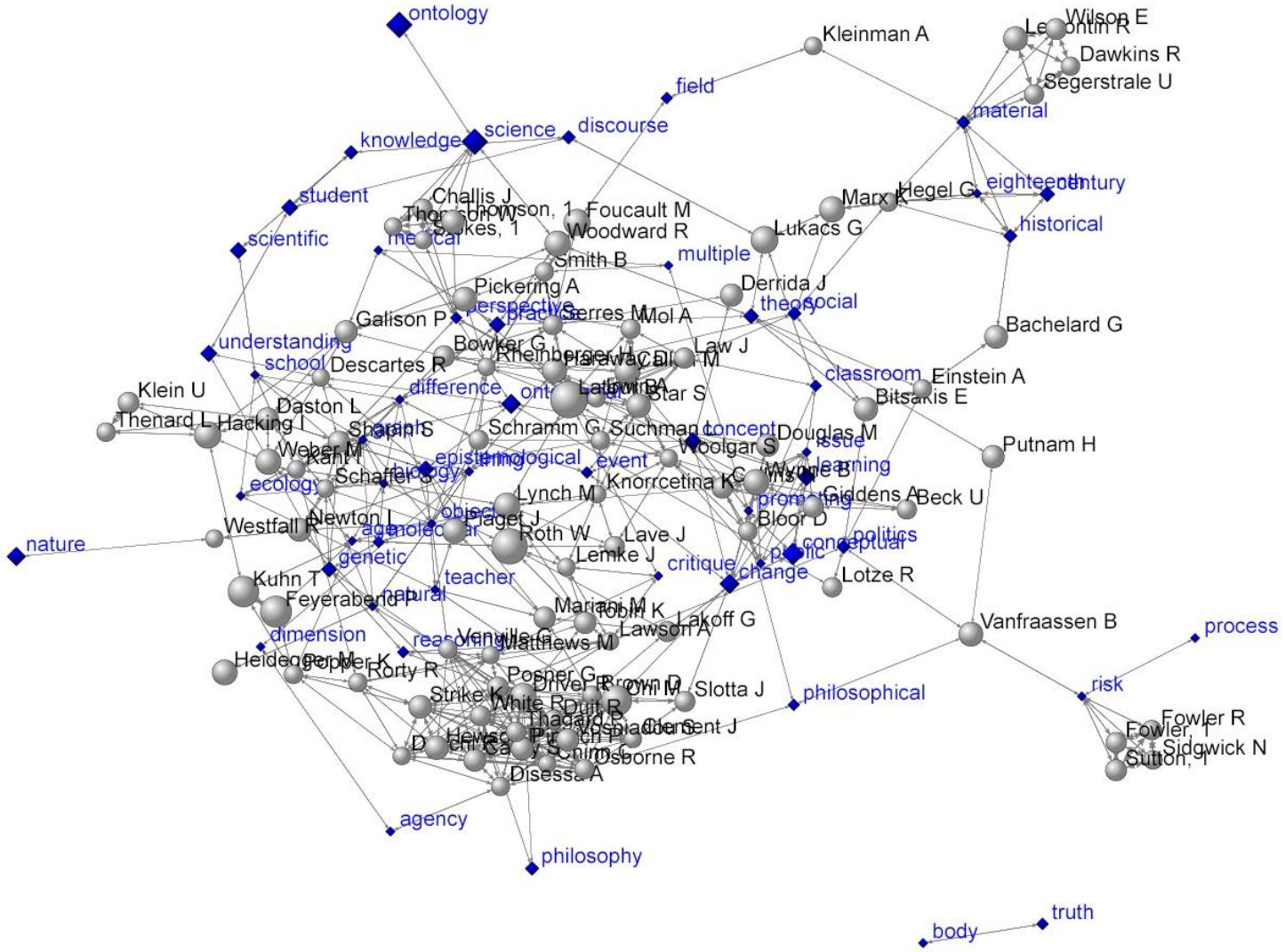


Figure 6: Heterogeneous map of 96 most-cited authors and 55 title words in citing documents (cosine > 0.3). A full and colored version of this map can be retrieved at http://www.leydesdorff.net/ontology/figure6.htm.

Notes

We would like to thank Steve Woolgar and Javier Lezaun and their colleagues at Oxford for the invitation to Sally Wyatt to participate in the workshop about the ontological turn in STS that they organized in June 2008, which sparked our interest in the topic. We are also grateful to colleagues in the STS Department at Maastricht University for the useful feedback they provided at the 2009 'summer harvest'. Hans Radder and Rein de Wilde also provided useful feedback on an earlier version. Sergio Sismondo organized the review process, and gave detailed comments which have been very valuable in preparing the final version. We received no financial support for the preparation of this article.

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[1] A topic search was conducted on 21 August 2009, using the *Social Sciences Citation Index (SSCI)* and the *Arts & Humanities Citation Index (A&HCI)*, for the publication years 1989-2008, using ontolog* as the search term. A topic search includes title, abstract and keywords. 'Subject Categories' are used by the Web of Science to classify journals into what we might otherwise refer to as disciplines, fields, areas.

[2] In the previous version (v. 4) of the Web of Science, the Web-of-Science Categories were called ISI Subject Categories.

[3] As one reviewer usefully suggested, one major use of 'ontology' as a term is in the field of bioinformatics in which it is used to refer to the object universe as registered through the contents of the fields in data forms. This is indeed correct and among the top journals overall that refer to 'ontology' are *BMC Bioinformatics*, *Bioinformatics* and the *Journal of Biomedical Informatics*. Many of these journals are included in the Web of Science subject categories of computer and information sciences. To an extent, this bioinformatics debate explains the increase of references to ontology in these categories.

[4] These Handbooks contain reviews, whereas the journal literature mainly contains research articles. In the 1995 *Handbook*, there is only a single reference to 'ontological gerrymandering' in a chapter by Ashmore *et al.* (1995). This is actually a quote from Woolgar and Pawluch (1985) about the boundary work social scientists do in order to make some social problems and assumptions open for analysis. In the 2008 *Handbook*, there is again a single reference to 'ontological engineering' in the chapter by Suchman (2008) which refers to how computer scientists decide what kinds of objects need to be represented in their models. Thus, the *Handbooks* could not be used for the operationalization of our research question because they do not reflect the increase in the use of 'ontology' found in

the journal literature, although future editions may do so given a delay between research and its further codification as shared knowledge.

[5] See http://www.4sonline.org/journals.htm (accessed 30 July 2009).

[6] The cosine between two variables is defined as follows:

$$\text{Cosine}(x,y) = \frac{\sum_{i=1}^{n} x_i y_i}{\sqrt{\sum_{i=1}^{n} x_i^2} \sqrt{\sum_{i=1}^{n} y_i^2}} = \frac{\sum_{i=1}^{n} x_i y_i}{\sqrt{(\sum_{i=1}^{n} x_i^2) * (\sum_{i=1}^{n} y_i^2)}}.$$

In bibliometrics, this measure is used because unlike the Pearson correlation it is non-parametric and therefore not sensitive to the skewed distributions and large numbers of zeros in representations of scholarly discourse such as co-word maps and citation analysis.

[7] For pragmatic reasons, we discuss the semantic maps as printed here, but wish to note that one is free to rotate or translate the maps since the axes of these representations have no substantive meaning.

The maps are drawn using the algorithm of Kamada and Kawai (1989) that optimizes the energy minimum when the links are considered as representations of springs.

[9] *Studies in History and Philosophy of Science* is not among the journals thus selected.

[10] The analysis is based on using the routine BibAuth.exe which is available at: http://www.leydesdorff.net/software/bibauth/index.htm .

[11] The references used for the construction of Figure 5 include book titles. No book titles were among the top-1% references.

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