

Unfolding the map: Making knowledge and ignorance mobilization dynamics *visible* in science evaluation and policymaking

Joanne Gaudet, University of Ottawa

AUTHOR'S NOTE: This is a preprint of a book chapter for the upcoming *International Handbook of Ignorance*. The text proposed here is subject to change in the final version. To quote the preprint: Gaudet, J. Forthcoming. Unfolding the map: Making knowledge and ignorance mobilization dynamics visible in science evaluation and policymaking. Pp. 1-19 in M. Gross and L. McGoey (editors), *The International Handbook of Ignorance*. Routledge. <http://routledge-ny.com/books/details/9780415718967/>

Section Five: Valuing and managing the unknown in science, technology and engineering

[T]he generation of Experiments being like that of
Discourse, where one thing introduceth an hundred more
which otherwise would never have been thought of.

(Grew 1673: A6)

[S]ince the faculties of Plants do often lie more recluse; it
is best therefore not wholly to acquiesce in such
Conjectures as their tastes or other properties may
suggest; but to subjoyn Experiment.

(Grew 1673: 41)

The main goal in this chapter is to explore how a mapping of knowledge and ignorance mobilization dynamics in science (Gaudet 2013: 179) can play a role in science evaluation and policymaking. The standard science epistemic map – where only knowledge is valued – is thus unfolded, making knowledge *and* ignorance mobilization dynamics more visible. An emphasis on mapping is in keeping with practices by natural scientists who construct visualizations for natural scientific knowledge, making it more

visible and thereby hopefully easier to communicate (Gross and Harmon 2014). The starting point for the chapter is not the proposed mapping, however; instead, it is in the seventeenth century with the above quotes from Nehemiah Grew in 1673.

The opening quotes capture the essence of epistemic dynamics in burgeoning scientific experiments¹ in the seventeenth century. The disproportionate (cf., ‘one thing introduceth an hundred more’) and dynamic interplay between knowledge and what remained unknown (cf., ignorance – ‘the faculties of Plants do often lie more recluse’, or nescience – ‘would never have been thought of’) were already evident for experimental natural philosophers (see Anstey 2005; Gaukroger 2006).

Natural philosophy (as the study of nature, Hannam 2010: 6) had then only recently split into speculative natural philosophy and experimental natural philosophy. Speculative natural philosophers did not systematically engage in observation or use experimentation to propose explanations for nature and its phenomena (Anstey 2005: 215). Moreover, the types of entities (ontological considerations) that were offered to support speculative natural philosophy explanations included “...inexplicable occult qualities, substantial forms, virtual extension, sympathies and antipathies” (2005: 221). In contrast, experimental natural philosophers delved into “...the collection and ordering of observations and experimental reports with a view to the development of explanations of natural phenomena based on these observations and experiments” (2005: 215).

¹ I focus on epistemic dynamics. This introductory discussion on experiments is not intended as a history of experimentation that investigates analytical, demonstrative, and synthesis functions in experimentation. An example of such analysis is Shapin and Schaffer’ (1985) history of early scientific experimentation. Pickstone (2001) for his part bemoans the lack of a typology for experimentation and proposes a history of experimentation that draws on biological and medical sciences (2001: chapter six).

What is more, as Johns suggests, is that the success of an experiment for experimental natural philosophers was at least in part tied to its ability to generate further experiments (1998: 470). Success viewed this way meant constructing and valuing new ignorance. Ignorance here refers to the limits and borders of knowing (see Gross 2010: 68). Moreover, ignorance is non-pejorative as what scientists know is not (yet) known in science (see Ivainer and Lenglet 1996; Logan 2009). For a seventeenth century experimenter, valuable ignorance could thus fuel further experimentation. The *intentional* and *explicit* knowledge and ignorance dynamic practices that natural experimental philosophers engaged in persist in contemporary science in and out of the laboratory (see Bhaskar [1975]2008: 58; Gross 2010: 30; Latour 2000; Overdeest et al. 2010).

The use of mapping is enlisted here to make scientific knowledge and ignorance dynamics – like those Grew (1673) and his fellow experimental natural philosophers engaged in over three hundred years ago – more visible (see mapping of ignorance typologies in Hess 2010: 5). In addition, mapping can make intentional and unintentional inclusion and exclusion of ignorance more visible. Thus, the underlying argument in the chapter is the following. Although science evaluation and policymaking typically focus on and value scientific knowledge – mapping of, and acknowledgement of, knowledge *and* ignorance mobilization dynamics is crucial to account for scientific practices of valuing ignorance (see Firestein 2012; Davies 2011; Roberts and Armitage 2008). The focus of the chapter is therefore intentionally on epistemic dynamics.

The chapter proceeds in two parts. First, I present mapping for knowledge and ignorance dynamics and their respective mobilization in science (Gaudet 2013: 179). It extends mapping of topologies for knowledge and ignorance developed by Gross (2010:

71). Second, harnessing mapping dynamics, I briefly explore two Canadian cases of science evaluation and policymaking. In the first case, I investigate the Council of Canadian Academies' consideration of expert opinion on knowledge gaps as a potential socio-economic impact indicator for science performance (Expert Panel on Science Performance and Research Funding 2012: 41). The case explicitly acknowledges the role of ignorance in science evaluation. In the second case, my attention turns to a decision by Health Canada, a federal department, to remove some calcitonin-containing drugs off the Canadian market following research on their potential cancer risk (Health Canada 2013b). The change highlights a need for evergreen² science policies that take knowledge and ignorance mobilization dynamics in science seriously. By evergreen science policy, I refer to policy that has emergent properties explicitly acknowledging potential new scientific knowledge or ignorance that can lead to a need for change in policy direction. Given that the focus in the chapter is on epistemic dynamics, I only briefly locate the second case within literatures on post-market surveillance and regulatory bodies (i.e., Carpenter, 2006; Lexchin, 2014). The chapter closes with reflections on the role of mapping in the sociology of scientific knowledge and ignorance.

Mapping knowledge and ignorance mobilization dynamics in science

In Figure 1.0, I present mapping for knowledge and ignorance mobilization dynamics in science (Gaudet 2013: 179) that was originally inspired from knowledge and ignorance topological mapping developed by Gross (2010: 71). Typically, only the top

² I acknowledge Dr. Amanda MacFarlane, a researcher at Health Canada, for having introduced me to the concept of 'evergreen' science policies.

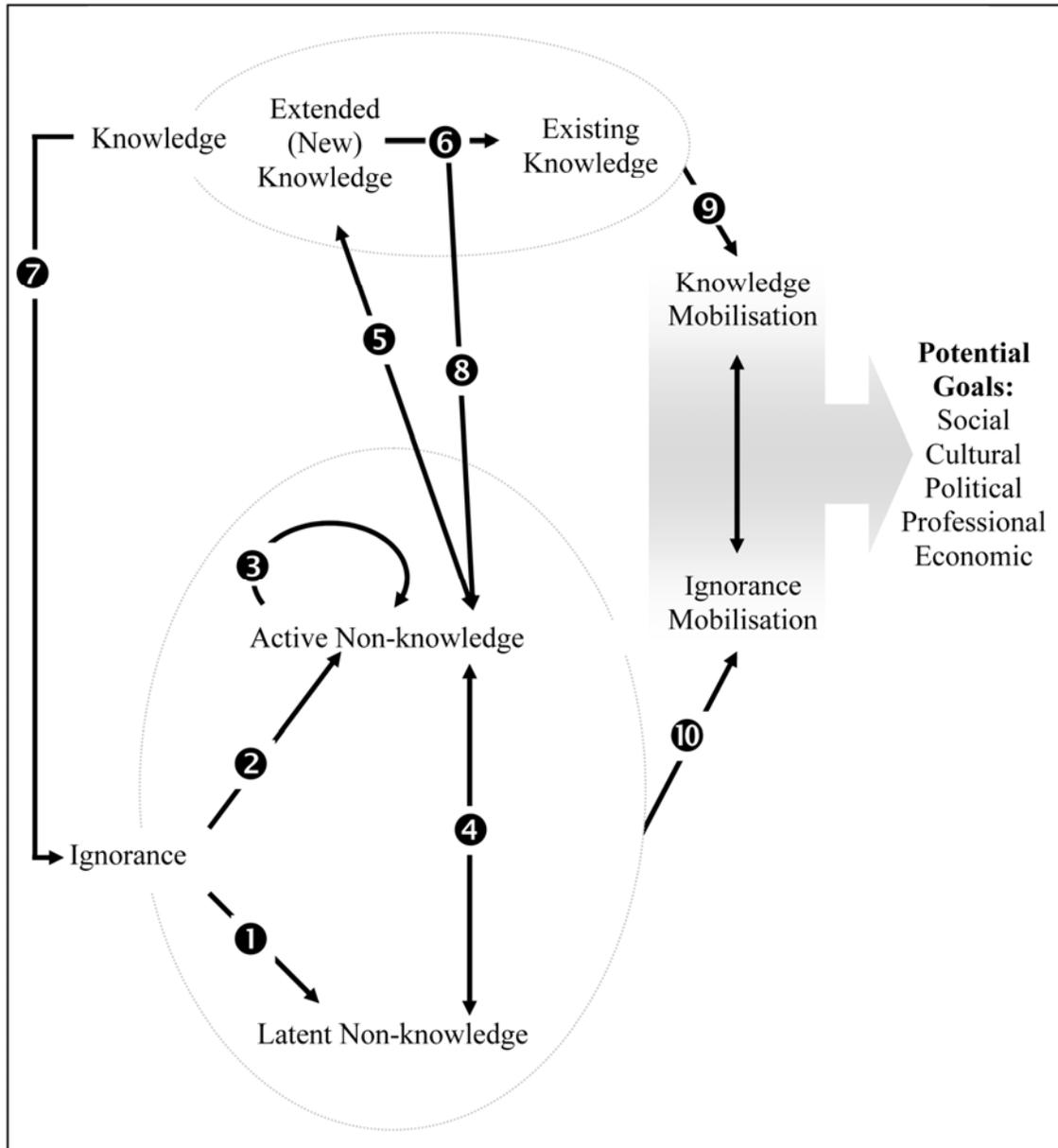
half of the map would retain the explicit attention of policymakers and science evaluators. In contrast, the unfolded mapping in Figure 1.0 attempts to convey scientific practices of dynamic and dialogical knowledge and ignorance construction and mobilization where new knowledge can lead to more ignorance, and ignorance itself can lead to more ignorance (see Smithson 2009: 24; Gross 2010: 173). Before looking at dynamics however, I tend to definitions.

Nescience here is understood as the complete absence of knowledge (Gross 2010: 68) and therefore lies outside of the mapping. Once constructed, however, and frequently in response to surprise, it can lead to ignorance and knowledge (2010). Surprise is used in the way Simmel (1922) proposed it where it can "...be freed from its psychological and sentimental meaning as a logical category for the relation between different contents" (quoted within Gross 2010:38). Therefore, "...something is surprising when a pre-existing set of experiences and a horizon of expectation turn out to be inappropriate, since [a given] situation contradicts any anticipation" (my adaptation in brackets, 2010:37). Essentially, a contradiction in anticipation can motivate a researcher to construct new ignorance to account for surprise.

Moreover, in keeping with Gross (2010: 49), knowledge refers to a justified belief connected to purpose (or use), and two sub-types are existing and new knowledge (Gaudet 2013: 173). The broader category of ignorance for its part refers to the borders and the limits of knowing (see Gross 2010: 68). Two ignorance sub-types are active non-knowledge and latent non-knowledge. Active non-knowledge denotes "...the limits and the borders of knowing that are intentionally or unintentionally taken into account for immediate or future planning, theorizing and action" (Gaudet 2013: 173). In contrast,

Figure 1.0. Model of knowledge and ignorance mobilization dynamics in science*

(Gaudet 2013:179)



*Numbering is for ease of reference and does not refer to a sequential process. Arrows are conceptual and sometimes depict causal relationships.

latent non-knowledge is *not* taken into account and therefore not mobilized by actors within or outside of science (examples in Frickel et al. 2010; Kempner et al. 2011). If it is eventually mobilized by actors, it exists latency to be constructed as new active non-knowledge. Finally, knowledge and ignorance mobilization, respectively, refer to the use of justified beliefs or the borders and the limits of knowing towards the achievement of goals (social, cultural, political, professional and economic) (Gaudet 2013: 175). These definitions already convey some relational dynamics, but a closer examination of Figure 1.0 renders their wider range.

Multiple actors including scientists, policymakers, stakeholders, brokers, and funders can engage in knowledge and ignorance mobilization (2013). A quick overview of Figure 1.0 starts with an understanding that linkages are conceptual and can sometimes depict causal relationships. Step numbering is solely for ease of reference to locate processes and dynamics at particular junctures in the model, for example, and do not refer to a sequential process. Existing knowledge, typically in written (print and electronic) cultural archives such as scientific journal articles and books, includes existing written ignorance (not displayed). Lastly, in spite of portraying a one-dimensional diagram, the model attempts to capture complexity and dynamic layers with recursive relationships that create new instances of ignorance or knowledge and their sub-types.

Starting on the left-hand side of Figure 1.0, the two overarching and related epistemic categories are knowledge and ignorance. Respective sub-types link within the overarching categories. As discussed above for example, new ignorance can *not* be mobilized and therefore remain excluded (and at least temporarily not valued by scientific actors) as latent non-knowledge (step 1). Alternatively, ignorance *can* be

mobilized and constructed as valuable active non-knowledge (step 2), active non-knowledge can lead to the construction of new active non-knowledge (step 3), and latent non-knowledge can eventually be constructed as active non-knowledge (step 4). Finally, new knowledge can join existing knowledge (step 6). Between the categories, knowledge can lead to the construction of more ignorance (step 7), active non-knowledge can lead to the construction of new knowledge (step 5), and judgements on manuscripts in journal editorial peer review (conceptualized between new and existing knowledge) can lead to the construction of new active non-knowledge (step 8).

Finally, the right-hand side of Figure 1.0 focuses on actors, mobilization, and goals. Actor knowledge (step 9) and ignorance (step 10) mobilization dynamics are distinct yet remain in tension and link with potential mobilization goals (i.e., social, cultural, political, professional, and economic). Here I highlight differential mobilization of knowledge and/or ignorance that actors can engage in. By this, I mean that actors can mobilize more or less knowledge and/or ignorance, thus differentially. An example is actors in a basic research laboratory who engaged in higher ignorance mobilization in comparison to lower knowledge mobilization in a biological sciences case study (Gaudet et al. 2012).

A last consideration is that my use of a model such as Figure 1.0 does not mean that I conceptualize knowledge and ignorance exclusively as property. Rather, I advance that competent actors engage in situated mobilization (see Wehling 2006: 87), be they scientists, policymakers, stakeholders, brokers, or funders. Lastly and in keeping with the main argument in the chapter, the overview of dynamics in Figure 1.0 renders scientific knowledge and ignorance dynamics visible and thus potentially useful for science

evaluators and policymakers. I use the model to explore two cases, starting with a first case in science evaluation.

Expert opinion on knowledge gaps as a socio-economic impact indicator in science evaluation

The first case focuses on a specific socio-economic impact stemming from scientific activity – ‘expert opinion on knowledge gaps’ (Expert Panel on Science Performance and Research Funding 2012: 41) – framed in a ‘Logic model for the selection of appropriate indicators’. The logic model was part of a project report entitled ‘Informing Research Choices: Indicators and Judgment’ by the Council of Canadian Academies (the Council). The board members for the Council who oversaw the project included representatives from the Royal Society of Canada, the Canadian Academy of Engineering, the Canadian Academy of Health Sciences, and the Canadian public (2012: ii). The logic model was presented as a “...common policy tool [that] can provide an instructive organizing structure for theoretical linkages between funding and the expected impacts and societal benefits from investing in discovery science” (2012: 40). Socio-economic impact here refers to an assessment of how results obtained from research are more broadly relevant (2012: 40).

The main element of interest in the case, ‘expert opinion on knowledge gaps’ (2012:41), was framed as a potential indicator of scientific socio-economic impact in the context of Canada’s Science and Technology strategy (2012:41). Expert opinion on knowledge gaps is of interest because it explicitly acknowledges potential scientific impact beyond what is known in science.

Referring to Figure 1.0, ‘knowledge gaps’ can be understood as active non-knowledge or valued ignorance. Constructed as potential socio-economic impact, it is intentionally taken into account for possible future use in planning, theorizing, and action inside or outside of academia. Actors could therefore mobilize this active non-knowledge to construct new knowledge (step 5) or potentially further new active non-knowledge (step 3). Furthermore, ‘expert opinion’ implies a competent actor (cf., a scientist) to construct a knowledge gap as valuable active non-knowledge. Once constructed, other actors can mobilize the active non-knowledge. For example, a policymaker can mobilize it to inform policy with political, social, and economic goals. Alternatively, a stakeholder or commercial actor could mobilize the active non-knowledge to construct a new research project or commercial venture, thereby meeting professional and economic goals.

For science evaluators therefore, socio-economic impact in this case refers to emergent properties when it considers the limits and the borders of knowledge. To be sure, knowledge gaps are not a final impact ‘product’. Impact instead rests in emergent relational potential for knowledge gaps as valuable active non-knowledge. Made visible in Figure 1.0, emergent relational potential can touch on several potential impact spheres including social, cultural, political, professional, and economic. From a focus on science evaluation in this first case, the second case shifts more specifically to scientific epistemic dynamics and science policy.

Knowledge and ignorance dynamics and evergreen science policies

The second case focuses on post-market surveillance by Health Canada that led to “...changes in the availability and recommended conditions of use of drugs containing

calcitonin” (Health Canada 2013b). A Government of Canada federal department, Health Canada’s mandate includes health-related policy, legislation, regulation, and activities such as drug approval, and post-market surveillance. The hormone in question, calcitonin, is naturally present in the human body and is known to increase calcium levels in the bones and lower these in the blood (European Medicines Agency 2012:1). Commercial synthetic forms of the hormone are used in pharmaceutical products. In Canada synthetic “[c]alcitonin is used as a nasal spray to treat osteoporosis (loss of calcium in bones) [...] and as an injection to treat Paget’s disease (a chronic bone disorder) and hypercalcemia (high blood calcium)” (Health Canada 2013b).

Especially relevant in the chapter is that initial conditions of use for calcitonin containing products approved nearly 30 years ago by Health Canada (Health Canada 2013a: 4) did not anticipate that long-term use of the products could potentially lead to increased risk of various types of cancer. The unanticipated increased cancer risks are understood in this case as nescience or the complete absence of knowledge (outside of Figure 1.0). As Lexchin (2014) advanced, “...a prolonged period on the market is no guarantee of safety” (Lexchin, 2014: e18). Understood within an epistemic framework, length of market use does not equate with safety, rather knowledge and active non-knowledge remain on ‘probation’ with respect to potential new ignorance.

Prior to this construction of nescience, active non-knowledge for synthetic calcitonin containing drugs had generally revolved around these drugs’ health impact on osteoporosis, Paget’s disease, and hypercalcemia. An example is research on nasal calcitonin’s ability to increase bone mass density and to lead to reductions in various types of fractures for individuals with osteoporosis. Newly constructed knowledge (step 5

in Figure 1.0) on the topic joined existing knowledge (step 6) (i.e., Tuck and Datta 2007: 530-531).

Once constructed however, nescience led scientists to produce new active non-knowledge (step 2) on the link between calcitonin products and cancer. Further research helped construct new knowledge (step 5) that joined existing knowledge (step 6) such as a difference in increased risk of cancer for long-term use with higher doses and intranasal use in comparison to short-term use with minimal effective doses through injection and infusion (Health Canada 2013: 2-3; European Medicines Agency 2012: 2). With this new active non-knowledge, the above active non-knowledge on the drugs' potential health impact for osteoporosis appeared to shift to latent non-knowledge (step 4).

In addition, active non-knowledge on the link between calcitonin products and cancer led to the construction of new active non-knowledge (step 3) pertaining to *how* calcitonin products could potentially lead to certain malignancies (cancers) (see limited scholarship of vitro research on human prostate cancer cell lines in Miacalcin team - Novartis 2013: 63-64). Not all types of cancer (or disease) with a potential link with calcitonin appear to have been considered for further research, however, and remain unstudied as examples of latent non-knowledge (step 1).

As the above dynamics illustrate, post-market surveillance performed by Health Canada and health regulatory agencies around the world (i.e., the European Medicines Agency and the Food and Drug Administration in the United States) at least *implicitly*, if not *explicitly*, acknowledges potential science knowledge and ignorance mobilization dynamics. Surveillance monitors unanticipated or surprising consequences with potential human health impact.

Post-market surveillance therefore constitutes an example of an “evergreen science policy” process if it explicitly places active non-knowledge and knowledge on ‘probation’ with respect to potential new knowledge or ignorance. I define evergreen science policy as policies that have emergent properties explicitly acknowledging the potential construction of new epistemic relations as portrayed in Figure 1.0 (cf., new active non-knowledge, new ignorance, or new knowledge). Evergreen policy is therefore flexible and accommodates refinement, development (see Parliament of Canada Standing Committee on Environment and Sustainable Development 2008), or perhaps dissolution in response to the construction of emerging epistemic relations.

For policymakers, the challenge in creating evergreen policies is to convey the potential for change in scientific knowledge and ignorance without appearing to compromise the validity of scientific knowledge framing the policy. Figure 1.0 can support policymakers to perform this task in two ways. First, in Figure 1.0 scientific knowledge and ignorance are not understood in linear and finite relation, but rather explicitly in dynamic and potentially dialogical relations. Validity therefore does not rest in knowledge stability, instead it remains probationary to potential anticipated change. Second, policymakers can use Figure 1.0 as a tool to educate stakeholders, partners, funders, and the general public on scientific epistemic practices. By doing so, these actors can see and learn to expect and value change in scientific knowledge and ignorance.

Moreover, a focus on epistemic dynamics here might wrongly convey simplicity in post-market surveillance. Simplicity belies underlying complexity. As Jasanoff argued, regulatory science is complex given that it is performed “... at the margins of existing knowledge” (Jasanoff, 1990:79) that not only entails knowledge production, but also

prediction, involving numerous actors and accountabilities (1990:77). Research shows that post-market surveillance is fraught with challenges including conflicting institutional relations of power over decision-making, problems with enforcement (Carpenter, 2006; Light, 2010), and potential increased exposure of users prior to the withdrawals of unsafe drugs (Lexchin, 2014: e18). Where post-market surveillance actors can enter an epistemic framework is in how they mobilize, or do not mobilize, new ignorance or knowledge and for which (perhaps conflicting) goals they do so, or not (steps 9 and 10).

Finally, the model can help policymakers and non-scientific actors understand and learn how to engage in the relationship between latent non-knowledge and active non-knowledge (step 4) in science. For example, policymakers wishing to enlist a wider range of non-scientific actors to participate in shaping publicly-funded science and science policy can use the model to illustrate how health issues that matter to citizens, as latent non-knowledge, can eventually be constructed as active scientific non-knowledge. This final consideration is part of wider dynamics on the democratization of science and technology and citizen participation in science policy (i.e., Callon et al. 2001; Kelly 2003; Rask 2008; Selin and Hudson 2010).

Conclusion

I advanced in this chapter that a model of knowledge and ignorance mobilization dynamics in science could play a valuable role in science evaluation and policymaking. In essence, the model represents the unfolding of the typical map focussed on scientific knowledge. In the first case, active non-knowledge was explicitly acknowledged in science evaluation (cf., the Council report). Understood within a model of knowledge and

ignorance mobilization dynamics (Figure 1.0), further potential epistemic relations (to new knowledge and/or active non-knowledge) and actor mobilization goals become more visible for science evaluators looking to account for impact as emergence.

In the second case, seeing post-market surveillance of a pharmaceutical product through a model of knowledge and ignorance mobilization dynamics (Figure 1.0) illustrated the multiplicity of new knowledge and ignorance mobilized, or not mobilized in the case of latent non-knowledge. It was also in the second case that I proposed the concept of evergreen policy with emergent properties explicitly acknowledging the potential construction of new epistemic relations. What is more, for policymakers, a model like that in Figure 1.0 could be a useful tool to account for validity in a context of expected change, and as a tool to educate and empower actors outside of science such as stakeholders, partners, funders, and the general public.

To conclude, I explore two implications from the use of a model of knowledge and ignorance mobilization dynamics in science evaluation and policymaking. First, such a model equips science evaluators and policymakers with concepts that reflect dynamic scientific epistemic practices. Second, there are at least two consequences of acknowledging such dynamics. Firstly, scientific knowledge can no longer be conceived of as permanent – it retains potential changing relations with ignorance. Secondly, active and latent non-knowledge can no longer be conceived of as permanently regarded or disregarded by scientists. Rather, scientific knowledge and active and latent non-knowledge retain expected and ongoing shaped and reshaped relations with knowledge and ignorance and their sub-types. Ultimately, the model highlights relational mobilization dynamics with valuable scientific knowledge and ignorance as was the case

for experimental natural philosophers in the seventeenth century. The unfolded map reflects a sociology of knowledge and ignorance.

Acknowledgements

I am grateful to the Principal Investigator of a PrioNet Canada research laboratory, Xavier Roucou, and his students and research assistants who inspired me to develop ignorance mobilization as complementary to knowledge mobilization and the mapping in Figure 1.0. The ideas, arguments, analysis, and remaining errors are solely mine, however, and do not necessarily reflect the views of individuals above. Funding was provided in part by a Joseph-Armand Bombardier Canada Graduate Scholarship from the Social Sciences and Humanities Research Council of Canada.

References

- Anstey, P.R. (2005) 'Experimental Versus Speculative Natural Philosophy', in P. R. Anstey and A. Schuster (eds) *The Science of Nature in the Seventeenth Century*, Netherlands: Springer.
- Bhaskar, R. ([1975]2008) *A realist theory of science*, London: Verso.
- Callon, M., P. Lascoumes, and Y. Barthe (2001) *Agir dans un monde incertain : essai sur la démocratie technique*, Paris: Seuil.
- Carpenter, D. (2006) "Reputation, gatekeeping and the politics of post-marketing drug regulation", *Virtual Monitor: Ethics Journal of the American Medical Association*, 8: 403-403.
- Davies, W. (2011) 'Knowing the Unknowable: The Epistemological Authority of Innovation Policy Experts', *Social Epistemology*, 25: 401-421.
- European Medicines Agency (2012) 'Questions and answers on the review of calcitonin containing medicines: Outcome of a procedure under Article 31 of Directive 2001/83/EC', London: European Medicines Agency.

Expert Panel on Science Performance and Research Funding (2012) 'Informing Research Choices: Indicators and Judgment - The Expert Panel on Science Performance and Research Funding', Ottawa: Council of Canadian Academies.

Firestein, S. (2012) *Ignorance: How it Drives Science*, New York: Oxford University Press.

Frickel, S., S. Gibbon, J. Howard, J. Kempner, G. Ottinger, and D.J. Hess (2010) 'Undone Science: Charting Social Movement and Civil Society Challenges to Research Agenda Setting', *Science, Technology, & Human Values*, 35: 444-473.

Gaudet, J. (2013) 'It takes two to tango: knowledge mobilisation and ignorance mobilisation in science research' *Prometheus: Critical Studies in Innovation*, 31:169-187.

Gaudet, J., N. Young, and M. Gross (2012) 'Ignorance is Power: Science in Practice Epistemic Mobilization Dynamics' Presented at the Canadian Sociological Association (CSA) 2012 Conference in Kitchener-Waterloo, May 28-June 2, 2012.

Gaukroger, S (2006) *The Emergence of a Scientific Culture: Science and the Shaping of Modernity 1210-1685*, Oxford: Clarendon Press.

Grew, N (1673) *An idea of a phytological history propounded together with a continuation of the anatomy of vegetables, particularly prosecuted upon roots*, London: printed by J.M. for R. Chiswell.

Gross, A.G. and J.E. Harmon (2014) *Science from Sight to Insight: How Scientists Illustrate Meaning*, Chicago: The University of Chicago Press.

Gross, M. (2010) *Ignorance and Surprise: Science, Society and Ecological Design*, Cambridge: The MIT Press.

Hannam, J. (2010) *God's Philosophers: How the Medieval World Laid the Foundations of Modern Science*, London: Icon Books.

Health Canada (2013a) 'Media lines: Information Update on Drugs Containing Calcitonin', Ottawa: Health Canada. Obtained under the Access to Information Act - October 9, 2013.

—. (2013b) 'Press Release: Important Changes to the Availability and Conditions of Use for Drugs Containing Calcitonin', Ottawa: Government of Canada.

Hess, D. (2010) 'Social Movements, Publics, and Scientists', Invited Plenary Lecture, Japanese Society for Science and Technology Studies, Tokyo.

Ivainer, T. and R. Lenglet (1996) *Les ignorances des savants*, Paris: Maisonneuve & Larose.

Jasanoff, S. (1990) *The Fifth Branch: Science Advisers as Policymakers*, Cambridge, MA: Harvard University Press.

Johns, A. (1998) *The Nature of the Book: Print and Knowledge in the Making*, Chicago: The University of Chicago Press.

Kelly, S.E. (2003) 'Public Bioethics and Publics: Consensus, Boundaries, and Participation in Biomedical Science Policy', *Science, Technology & Human Values*, 28: 339-364.

Kempner, J., J.F. Merz, and C.L. Bosk (2011) 'Forbidden Knowledge: Public Controversy and the Production of Nonknowledge', *Sociological Forum*, 26:475-500.
Latour, B. (2000) 'Du principe de précaution au principe du bon gouvernement', *Études*, 3934: 339-346.

Lexchin, J. (2014) "How safe are new drugs? Market withdrawal of drugs approved in Canada between 1990 and 2009", *Open Medicine*, 8: e14-e19.

Light, D.W. (2010) 'Bearing the Risks of Prescription Drugs', in D.W. Light (ed) *The Risks of Prescription Drugs*, New York: Columbia University Press.

Logan, D.C. (2009) 'Known knowns, known unknowns, unknown unknowns and the propagation of scientific enquiry', *Journal of Experimental Botany*, 60: 712-714.

Miacalcin team - Novartis (2013) 'Briefing Book: FDA Joint Reproductive Health Drugs and Drug Safety and Risk Management Advisory Committee Meeting on the Benefit/Risk of Salmon Calcitonin for the Treatment of Postmenopausal Osteoporosis'. Available
<http://www.fda.gov/downloads/AdvisoryCommittees/CommitteesMeetingMaterials/Drugs/ReproductiveHealthDrugsAdvisoryCommittee/UCM341781.pdf> (accessed October 12 2013).

Overdeest, C., A. Bleicher, and M. Gross (2010) 'The Experimental Turn in Environmental Sociology: Pragmatism and New Forms of Governance', in M. Gross and H. Heinrichs (eds) *Environmental Sociology: European Perspectives and Interdisciplinary Challenges*, New York: Springer.

Parliament of Canada Standing Committee on Environment and Sustainable Development (2008) 'Evidence'. Available
<http://www.parl.gc.ca/HousePublications/Publication.aspx?DocId=3445464&Mode=1&Language=E> (accessed July 27 2013).

Pickstone, J.V. (2001) *Ways of knowing : a new history of science, technology, and medicine*, Chicago: University of Chicago Press.

- Rask, M. (2008) 'Foresight — balancing between increasing variety and productive convergence', *Technological Forecasting & Social Change*, 75: 1157-1175.
- Roberts, J. and J. Armitage (2008) 'The Ignorance Economy', *Prometheus*, 26: 335-354.
- Selin, C. and R. Hudson (2010) 'Envisioning nanotechnology: New media and future-oriented stakeholder dialogue', *Technology in Society*, 32: 173-182.
- Shapin, S. and S. Schaffer (1985) *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life*, Princeton, NJ: Princeton University Press.
- Smithson, M. (2009) 'The Many Faces and Masks of Uncertainty', in G. Bammer and M. Smithson (eds) *Uncertainty and Risk: Multidisciplinary Perspectives*, Sterling, VA: Earthscan.
- Tuck, S.P. and H.K. Datta (2007) 'Osteoporosis in the aging male: Treatment options', *Clinical Interventions in Aging*, 2: 521-536.
- Wehling, P. (2006) 'The Situated Materiality of Scientific Practices: Postconstructivism – a New Theoretical Perspective in Science Studies?', *Science, Technology & Innovation Studies*, Special Issue 1: 81-100.