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AN ILLUSTRATIVE PHENOMENOGRAPHIC CASE STUDY:

CHARTING THE LANDSCAPE OF

"PUBLIC UNDERSTANDING OF SCIENCE"

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ABSTRACT

A cross-disciplinary literature review returns conflicting renditions on the nature of science, science's place in society, and the public understanding of science. The phenomenon of science appears as many things to many people—a situation consistent with a phenomenographic non-dualist ontology that accepts a single, but variably experienced, real world. This study begins a process for comprehensively charting the landscape of *Public Understanding of Science.* In foregrounding the reflexive interplay of science and society, the resultant typography of science could, in turn, inform a mindful evolution of science curricula. In this study, a phenomenographic analysis of *Public Understanding of Science* journal article, "Fantastically reasonable: Ambivalence in the representation of science and technology in super-hero comics" (Locke, 2005) illustrates the phenomenographic process and provides a model for the application of phenomenographic methodology to systematically chart the nature of science as publicly experienced and understood.

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CHAPTER 1. INTRODUCTION AND RATIONALE FOR STUDY

Three key bodies of literature motivate and inform this study: (a) large scale studies of science literacy and public attitudes toward science (Bauer, Durant, & Evans, 1994; Besley & Shanahan, 2005; Bodmer & Wilkins, 1992; Burka, 1997; Campbell, 2002; Eurobarometer 55.2, 2001; Lederman, Wade, & Bell, 1998; Miller, 1998; Miller, Pardo, & Niwa, 1997; NSB, 2004); (b) descriptive investigations into those factors associated with world views and particular beliefs that run counter to science's naturalistic perspective (Coker, 2001; Craig, 1997; Gray & Mill, 1992; Kaminer, 1999; Lett, 1992; Locke, 2002; Manohar, 1997; Norris, Phillips, & Korpan, 2003; Ryan & Aikenhead, 1992; Sagan, 1997; Shermer, 1997; Yates and Chandler, 2000); and more recently (c) research into the social representations and meanings ascribed to science, both as interpreted and presented by popular media and as reflexively understood and expressed by various audiences within the realms of *expert, public, expert as public, and public as expert* (Fortun & Bernstein, 1998; Gregory & Miller, 1998; Jemison, 2003; Levy-Leblond, 1992; Lewenstein, 2002; McComas & Olson, 1998; Nelkin, 1995; Rose, 2003; Sturgis & Allum, 2004; Toumey, 1996).

Increasingly, adequate science literacy is seen to encompass more than basic content knowledge (Miller, 1998). Science curricularists and governments, particularly in Europe and North American cultures, press for improved instruction, not only of science content, but also of the processes and natures of science and technology (AAAS, 1993; Council of Ministers of Education of Canada [CMEC], 1997; Cross & Fensham, 2000; Hurd, 1997; Marshall, Scheppler, & Pamisano, 2003; Millar, Leach, & Osborne, 2000). Yet the very natures of science [NOS] and their existence as separate from technology remain hotly contested, even and perhaps especially, among academics (Osborne et al., 2003). Meanwhile, discrepant images and conceptions about science and scientists proliferate in popular culture (Driver, Leach, Millar, & Scott, 1996; Fortun & Bernstein, 1998; Nelkins, 1987/1995; Nisbett, 2005b; Sjoberg, 1997; Toumey, 1996).

Western science's emergence in and through elite contexts like the Royal Society, founded in 1660, served historically to legitimize and privilege its epistemology over other ways of knowing the natural world (Cooter & Pumfrey, 1994; Saul, 1992). Yet over the past several decades, scholarly analyses of the social natures and motives of science have questioned science's legitimacy and assumed privilege (Collins & Pinch, 1998; Harding, 1991; Keller, 1998). In a translation process from ivory tower camps to publics, the debates (e.g., Gross, Levitt, & Lewis, 1996; Haack, 2003; Koertge, 1998; Saul, 1992)—dubbed the science wars—have catalyzed and popularized a present growing and, in instances, undiscriminating anti-science sentiment (Abraham, 2005; Holton, 2002).

If science literacy is desirable—however and whoever chooses or seems entitled to define that concept—the defining process cannot afford to dismiss multiple existent images and conceptions about science's nature. That these persist should tell us something about the articulation between science and public and about the multifaceted nature of the current infrastructure and enterprise that we popularly experience as science in the western world.

Studies into literacy have traditionally taken a deficit approach whereby researchers judge participant scores against a requisite threshold of scientific knowledge deemed adequate for negotiating science-related decisions in a liberal democracy (Lewenstein, 2002; Sturgis & Allum, 2004; Trefil, 2003). The approach—beginning from measures of literacy according to science's expectations—invariably laments inadequate public science knowledge while inadvertently marginalizing local knowledge, ethnoscience, and other alternatives to a western science worldview (e.g., Miller, Pardo, & Niwa, 1997; NSB, 2004). Subsequent calls for educational reform persist (Fensham, 2000; Fuller, 2002; Lederman, 2003a ; McComas, et al., 1998; Roth & Desautels, 2004), leaving teachers—themselves often sharing the same so-called "public inadequacies"—with the task of implementing proposed remedies (Abd-El-Khalick & Lederman, 2000). Implicit throughout is a belief that "to know science, as we science people know it, is to love it." Yet, knowing, much less articulating, the nature of science is not so easy—even among those philosophical and sociological experts who make it a lifetime pursuit (Osborne et al., 2003).

Over the last half century, education reform movements have evolved according to changing beliefs about: (a) the nature(s) of science, (b) what all citizens should know about science and (c) how best to manage an educational system to deliver science knowledge (Duschl, 2000; Duschl & Hamilton, 1998; Hurd, 1997; Lederman, 2003a, 2003b; Lederman, Wade, & Bell, 1998). Certain assumptions—about what counts as science, what constitutes its methods, where its boundaries begin and end, and who gets to define these—are, in practice, contentious (Eflin, Glennan, & Reisch, 1999; Osborne, et al., 2003). Yet the answers to these questions underpin the various experiences[1] and understandings of and about science's nature (McComas, Clough, & Almazroa, 1998). If the goal is a smoother articulation between science and public, then a first step should be an examination, indeed, a charting of the landscape of the natures of science as experienced by and amongst various publics.

From popular culture to ivory tower, inconsistent images of science proliferate. The issue is less one-sided and more complex than a read of the literature from a particular camp might indicate. Though recently, perspectives and interpretations have, at times, taken greater breadth and sought convergences (Lewenstein, 2002), for the most part, inquiry direction, design, and outcome still differ considerably depending on the discipline directing the study. Historically, accounts of the nature of science, as portrayed to the public and presented in schools, reveal a fickle relationship, plagued by the pull and tug of multiple interest groups each with a stake in the economic, political, or social fallout of actions taken or not taken on the basis of science directives (Chalmers, 1999; Hurd, 1997).

[1] Central to the present phenomenographic approach is an understanding of experience as the apprehension of an individually and socially co-constructed reality. Although we gain rudimentary experience directly through our senses, experience acquires meaning and definition through cognitive processing and subsequent reflection and re-assemblage. To experience is to bring past to bear on the present. We come to know a phenomenon—that is, to develop knowledge about something (to learn)—through multiple forms of sensory and non-sensory experiences of that phenomenon. The accumulation and interaction of such knowing shapes a dynamic knowledge of both personal and social dimension. Thus, for the purposes of this study, the acts of, for example, thinking, viewing, feeling, perceiving, doing, apprehending, conceptualizing, imagining, and understanding all entail instances of experiencing. (Marton, 1996; pp. 84-85, Pramling, 1996; & pp. 43-44, Prosser, 2000) (See *The Object Of Research: Experiencing And The Nature Of Awareness*, Chap 3.)

Quantitative analyses report various demographic criteria that load onto science literacy but leave much unexplained. Intelligence, family background, degree of religiosity, and education have been shown to affect, to some degree, one's openness to alternatives to mainstream scientific explanations and prescriptions. Again, much variability in such openness is left unexplained (Craig, 1997; Gray & Mill, 1992; Gray, 1992; Manohar, 1997; Marshall, Scheppler, & Palmisano, 2003; Mill, 1990; Miller, Pardo, & Niwa, 1997; Norris, Phillips, & Korpan, 2003; Priest, 1995; Royalty, 1995; Yates and Chandler, 2000). The intermediary role on public science literacy of public conceptions and experiences about the character of science, only beginning to be examined, is a conspicuous candidate in accounting further for the variability in these quantitative studies.

Given that the depth and breadth of current science content is well beyond the scope of individual understanding (Rose, 2002), it behooves the citizen to exercise selective attention when it comes to science claims and, in the absence of understanding, to use other criteria for judging claims made in the name and authority of science (Gregory & Miller, 1998). Selective attention and opinion would both influence and be influenced by existent levels of literacy. A mediating factor lies in the ready images, impressions, and awarenesses of science replete through culture. Sociological investigations into the uptake of science highlight the important role of trust in accepting science's authority, as against competing authorities (Bauer, Petkova, & Boyadjieva, 2000).

To date, and to the best of my knowledge, no study has assembled public understandings of science into any sort of coherent typographical mapping. Such a map would provide a useful tool for investigating possible relationships between understandings about the social phenomenon of science, the conditions of science literacy, and public willingness to trust knowledge or heed directives offered in its name. Unraveling the interplay between the quality and character of public awareness of science and the public uptake of and interaction with science can inform approaches to science education, certainly in terms of graduating a scientifically responsible population, but also in moving toward a socially responsible and responsive scientific enterprise. Moreover, a map detailing existent conceptions of the phenomenon of science would represent a collective wisdom—a common sense of science; that is, the sense that common publics bring to their experience of science. To some extent, the very nature of science entails all conceptions and none in particular.

In any case, the influence of public ideas and impressions about science on people's subsequent apprehension of and interaction with science ought not be left to idle speculation. Phenomenography, a methodology within the paradigm of social cartography, affords a suitable lens with which to systematical examine documented experiences/understandings of a phenomenon—in this case science—and to subsequently chart the variation across and within categories of experience/understanding of that phenomenon. The present work illustrates the process by beginning with a phenomenographic analysis of a single study and suggesting how data, thus obtained, might contribute to the unfolding of a full phenomenographic understanding of the structure of awareness of science. Accordingly, this current paper sets both motive and method for a typographical mapping of *Public Understanding of Science.* The decisive work, in the form of a complete phenomenographic map, remains the promise and hope for future research.

CHAPTER 2. REVIEW OF THE LITERATURE

In the pages that follow, I sift and sort through the natures, awarenesses, and experiences of science evidenced in diverse literatures about science and the public. In the reading, expect multiple and conflicting perspectives together with a presentation style that strives to remain true to the intentions of the various authors. This study seeks *to accurately describe multiple experiences of the nature of science*. In like spirit, the literature review seeks *to accurately describe the multiple scholarly interpretations of the nature of science and of science in public*. Such an approach is consistent with a phenomenological methodology—one that takes as premise that all we can know about an existent reality, in this case science, is our experience of that reality. In short, I strive to keep out of the mix my opinions on both the reported natures of science and the public understanding of science. To attempt otherwise would compromise, at the outset, the goal of an authentic representation of the current literature about perspectives on science—these as experienced from within the scientific community, without the scientific community, and at the nebulous edges of science and non-science.

The first part of the review examines large-scale, government-sponsored assessments of public science literacy, primarily in western cultures. Over the past several decades, authors of these studies have lamented what they deem a disturbing mismatch between what the public ought to know about science and what the public appears to understand about it. In contrast, more recent research in social representations uses image study (metaphorically speaking) to tap the complexity of science in culture. As we consider the ways that science can grate against alternative worldviews, we begin to appreciate the motivations behind recent transitions in research and perspective: from one-way science-to-citizen communication and evaluation to more contextual study. Evidence, that the degree to which one's trust and belief in authority influences the perceived legitimacy of knowledge proffered by that authority, compels us to consider multiple influencing factors—notably the stock of available awarenesses of science—on the public uptake of science.

The first portion of the literature review sets multiple reasons for the application of phenomenographic study toward a problem now emerging as the need for deeper and broader understanding of the sites of interaction of the scientific community and the general public[2]. Attention to two-way communication of and about science serves to broaden the field of perspectives and thereby better inform our understanding of science in culture. The second part of the literature review moves to a closer description and further distinction of the nature of image, experience, and awareness—specifically how, as sensed and communicated artifacts of the social representations of science, these evolve with/in complex systems of human collectives.

Finally, with the rationale for studying conceptions of the phenomenon of science outlined and their character described, I turn to existing literature in search of a definition of the thing whose nature we desire to study, namely, science. Here we encounter yet another challenge, for the natures of science, conceptualized even by

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[2] I use the term public and general public for ease of expression, fully acknowledging that by public I mean a hypothetical construct that in practice does not exist as any coherent whole. Further, the scientific community, itself loosely defined, must include members of that general public—boundaries being both mutable and contextual.

scientists, science curricularists, science studies scholars, and students of science, do not conform to any consistent picture. This disjointedness is however only problematic from either of two perspectives: (a) in the case where the scientific community desires to communicate an essentialist, single-natured view of science or (b) where individuals experience distress over a multiple-natured science. Significantly, the literature describing science's nature is lean on using public perspectives to inform that description. Indeed, instances of public awareness of science—be they in the form of social representations or individually recounted narratives—have only recently entered the legitimate arena of study.

Lastly, I introduce the *Public Understanding of Science* journal—home to a growing body of research that attends to the interaction of science and public. Since its inception in 1992, a sizable number of studies have systematically examined various public representations and individual experiences of science. Having developed in the first two part of the review the rationales for scrutinizing instances of science in public, the last section presents opportunity. The journal already offers a pool of over 50 relevant studies, making the presently proposed investigation timely. By probing these collected works for emergent themes and patterns it is now possible to begin charting the landscape of public awareness of science.

Social Representations, Science Literacy, and the Public Understanding of Science

Conceptions of a Problem

The history of science's intersection with the public is one of changing perspectives on who constitutes the public, what a theoretical general public should know about science, what it actually knows, and what the scientific community—or those speaking on behalf of that community—can and should do about it. That history is traceable through the overt and implied images of science found in communications of and about science in education, media, and scholarly writing. Strong voices, especially from and on behalf of the scientific community, persist in calling for greater public understanding of science. Meanwhile, questions about, "Science literacy on whose terms? And according to whose perspective?" gain momentum.

The current era is witness to continued remonstrations, spawned from within the scientific community, urging responsible consumption of science knowledge. Among other warnings, none sound more urgently than the call for pre-emptive action to ward off uncommon and potentially catastrophic consequences of rampant and unchecked human activities—these activities, themselves fueled to unwieldy proportions by the ever-broadening energy-, matter-, and life-altering tools of technology (Council of Ministers, 1997; Goekler, Bush & Wheeler, 2003; Holton, 2002; NSTA, 2003; Levy-Leblond, 2002). In response, voices ricochet in public spaces, denying the urgency and relevance of both the warnings[3] and the authority of the scientific community. Citizens, seeking solutions to the challenges of everyday life and finding but limited answers in the scientific community's seemingly sterile regime, turn to more sympathetic ears for comfort and promise (Gregory & Miller, 1993; Ramaley, 2003; Toumey, 1996).

Meanwhile, in the messy public realm of democratic science, a "larceny" of what anthropologist Christopher Toumey terms the "hermeneutics of science" (1996,

[3] Significantly, the "first of a series of US-Soviet conferences on the social and political dimensions of science and technology [held 2-3 May 1991] was devoted to 'Anti-Science Trends in the United States and the Soviet Union'" (Holton, 2002, p. 103).

p. 164) flourishes. For example, proponents of intelligent design borrow the scientific jargon to re-package creationism as scientific theory and argue for its inclusion in science school curricula (*Kitzmiller v. Dover Area School District*, December 20, 2005)[4]. In another example of Toumey's hermeneutic larceny, an actor wearing a white lab coat—who but plays a medical doctor in a daytime soap—affords sufficient credibility to market a common drugstore medication in television advertisement[5]. And, in my own hometown, a self-described science laboratory uses the equivalent of a Weegie board to conduct so-called scientific analyses of spit samples taken on Kleenex tissue[6]. Repeatedly, the signs and symbols of the scientific community are unabashedly borrowed in public places to corroborate other meanings and values—mimicking scientific authority even as that authority is diluted. Further, "those who are creative with symbols and meanings, whether scientists or not, have a distinct advantage over those who try to conform to the intellectual purity of the scientific research ethos" (Toumey, 1996, p. 161). In counterbalance, individuals and organizations representative of the scientific community[7] increasingly work to

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[4] In a landmark decision, reminiscent of the 1987 ruling against the teaching of creationism as an alternative theory to evolution in science classes, Judge Jones (December, 2005) stated that, "we have addressed the seminal question of whether ID is science…. [I]t is not,… moreover ID cannot uncouple itself from its creationist, and thus religious, antecedents" (p. 136).
[5] In this 1988 commercial the actor openly says, "I'm not a doctor, but I play one on TV." In Toumey's reckoning, "if a real physician is a symbol of medical science once removed, and if an actor who pretends to be a doctor,… is a symbol twice removed, then the actor who did not even pretend…was thrice removed" (p. 3). Yet, to pitch the product, "he was an effective simulacrum of the authority of medical science" (p. 3).
[6] This was a personal experience of mine at a local homeopathic practitioner.
[7] For example, Americans like Carl Sagan, Paul Kurtz, and Michael Shermer, and American organizations such as the Center for the Scientific Investigation of Claims of the Paranormal [CSICOP], the Union of Concerned Scientists, and the Center for

maintain science's integrity, safeguard against misrepresentations, investigate suspect claims made in science's name, and debunk[8] unsubstantiated claims.

According to a growing body of multi-disciplinary inquiry into the interplay of science and culture, these debates and distortions surrounding science can mire people in confusion, uncertainty, and mistrust toward science and the scientific community (Fortun & Bernstein, 1998; Gregory & Miller, 1998; Marshall, Scheppler, & Palmisano, 2003; & Toumey, 1996). Given the futility of fully grasping all the relevant scientific information of the day, the ability to know when and what to trust in science and to distinguish science from non-science gains utmost importance. Put differently, science literacy, however defined, has reason to flounder in a climate where individuals are left to wonder what and how much to believe when it comes to claims made in the name, or at least the guise, of science. Further, even if such truths be known, there remain practical questions about how much personal agency and influence can really be possible within the boundaries of lived experience. In short, the citizen asks, in my everyday decisions, how much, if at all, should I take science into account? It is a reasonable question.

Inquiry focus much of their work on investigating and countering unsubstantiated claims.

[8] The strategy of debunking extends from a deficit model of literacy that sees problematic beliefs as evidence of ignorance and seeks to correct public thinking by supplying the missing information. This approach is reminiscent of Berger and Luckmann's (1967) nihilation strategy for neutralizing threats to an existing symbolic universe. Nihilation acts as a kind of negative legitimation by denying "the reality of whatever phenomena or interpretations of phenomena do not fit into that universe" (p. 114). It does so either by giving the deviant phenomena a negative ontological status or by accounting "for all deviant definitions of reality *in terms of* concepts belonging to one's own universe" (p. 115). Both strategies prevail among the debunkers who, as a matter of observation, appear to cluster in the United States. Among Europeans and Canadians there is greater emphasis on improved two-way communication between science and the public (Locke, 2002).

The Argument of Scientific Literacy for Stewardship

> This world of ours is a new world, in which the unity of knowledge, the nature of human communities, the order of society, the order of ideas, the very notions of society and culture have changed and will not return to what they have been in the past…. What is new is that in one generation our knowledge of the natural world engulfs, upsets, and complements all knowledge of the natural world before. (Oppenheimer, 1963 in Hurd, 1997, p. 4)

At multiple frontiers, information from various scientific communities increasingly inform, invoke, and promote particular political, economic, ethical, and social choices and actions on various levels from personal to global. At the same time, the above themes of inadequate public science literacy and a belief that "universal science literacy is a requirement for a truly participatory democracy" (Jemison, 2003, p. 187) fuels calls for improved communication of science in schools and elsewhere. In this perspective, sound public understanding of science's content, processes, and nature is conceptualized as the antidote to ill-conceived personal choices and irrational behaviour, which, taken *en masse*, can accumulate large-scale undesirable consequences.

Offering, as analogy, the demise of civilization into the dark ages, physicist and science historian, Gerald Holton considers science literacy instrumental in warding off impending "erroneous policy", "social instability", and global disequilibrium (2002, p. 105). Scientists from the Center for Inquiry, Union for Concerned Scientists, and Quackwatch regularly debunk supernatural claims about natural phenomena and offer strategies grounded in the nature of science to help laypeople distinguish science from its imposters.

Science literacy as necessary to prudent public stewardship of science knowledge, technology, and research in the 21st century resonates across science curricular documents (AAAS, 1993; Council of Ministers of Education of Canada [CMEC], 1997), and with the voices of scientists and researchers in any number of specializations, for example: science education and literacy (Cross & Fensham, 2000; Lederman, 2003b; Marshall, Scheppler, & Palmisano, 2003), assessment of public science literacy (Miller, Pardo, & Niwa, 1997), science communication (Gregory & Miller, 1998), anthropology (Toumey, 1996), philosophy and history (Fortun & Bernstein, 1998), sociology and education (Goekler et al., 2003) and astronomy and space science (Carl Sagan, 1997). James Trefil (2003) summarizes the perceived threat of persistent and inadequate science literacy:

> In a society, that is becoming increasingly driven by science and technology, a society in which the citizenry is increasingly called upon to deal with issues that contain a large scientific or technological component, this kind of scientific literacy isn't a luxury—it's a necessity. *Without it, our democratic system would degenerate into one in which decisions are made either by an intellectual elite or by demagogue-driven mobs* [italics added]. (p. 151)

The above argument for improved one-way science communication from scientist to public rests on two assumptions: (a) that, *in ways that matter,* inadequate public science literacy is the case; that is, the public is deficient and (b) that sufficient science knowledge is both *definable and attainable.*

In the first instance, a counterargument says that perceived deficiencies in science literacy need not be construed in terms of a deficient public. Instead they may well signal an efficient public that selectively attends to science on a need-to-know basis (Aikenhead, 1998; Fensham, 2000; Gregory & Miller, 1998; Nisbett, 2005a). Likewise, where understanding is unattainable or too time-intensive, the use of trust at a social level, to compensate for deficiencies at a cognitive one, "makes knowledge and understanding redundant" (Gregory & Miller, 1998, p. 100). Moreover, "literature of the past decade increasingly questions the criteria upon which science literacy has been traditionally measured (Lewenstein, 2002; Miller, S., 2001; Sturgis & Allum, 2004). It asks, for example: How does knowing that a proton is smaller than an atom assist in deciding whether or not to support genetically modified organisms?

In the second matter, notable hurdles compromise the degree to which sufficient science knowledge is definable and attainable and this is true for diverse publics and scientist-as-public alike. These hurdles include:

The sheer accumulation of scientific knowledge, the multiplicity of perspectives taken to any given phenomena, and the depth of specificity within fields of inquiry;

Variability in methods across science disciplines and ongoing contestation of science's nature in general (Chalmers, 1999; Driver, Leach, Millar, & Scott, 1996; McComas, Clough, & Almazroa, 1998; Ryan & Aikenhead, 1992); and

Inconsistencies in delineating boundaries or pivotal transition points from science to non-science, for example: (a) as implied in notions of quantitative versus qualitative research and differences as one moves from the hard sciences to transdisciplinary work and the social sciences (*c.f.*, AAAS, 1993; Driver, Leach, Millar, & Scott, 1996; Schick & Vaughn, 2002); (b) in regards science, technology, and the existence and nature of something called technoscience in between (*cf* Hurd, 1997, chap. 5; Ryan & Aikenhead, 1992; Rose, 2002), (c) in attempts to pry legitimate science from non-scientific imposters (see Shermer, 1997; Toumey, 1996); and (d) in transitioning from "an outdated habit of linking the quantitative to the scientific" when such habitual linking is highly inappropriate in the non-linear, non-Euclidean-based, dynamic sciences of complex and fractal-like systems (p. 319, Davis & Sumara, 2005).

Science and Public at Odds: Conflicting Worldviews

Complicating these practical limitations on science literacy, oft-inconsistent, contradictory, and questionable reports in newly publicized science (Campbell, 2002; Ioannidis, 2005; Ubelacker, 2005) erode public trust. Researchers looking into the nature of science note an unwieldy inquiry infrastructure that increasingly challenges long established and comforting ways of knowing, being, and acting (Dacey, 2004; Fortun & Bernstein, 1998, Nisbett, 2005a; Sturgis & Allum, 2004). In negotiating perceived incongruencies, individuals can, to varying degrees and in varying contexts, oppose, dismiss, compartmentalize, qualify, or embrace the authority of the scientific community as against the authority of competing worldviews (Nisbett, 2005; Zeidler, Walker, Ackett, & Simmons, 2002). The interrelationships within an individual's understanding about science—including the particular details of the science topic at issue, the epistemological nature of science in general, the perceived and actual accessibility of sense-making through scientific methods, and the trustworthiness of scientists and their work (Sturgis & Allum, 2004)—will influence willingness to support the scientific community and to use science knowledge to inform behaviour. The degree of endorsement of particular science givens and the ultimate choice to act in ways consistent with that endorsement will also depend upon such individual and social factors as: (a) the perceived net costs and benefits (emotional, social, and material) of accepting and acting on science findings as understood (Bell, 2003; Corbett, 2005); (b) the actual and perceived ability to adapt behaviour according to these findings (Corbett, 2005); and (c) the degree of attachment to alternative perspectives (Lett, 1992).

Means for Understanding the Natures of Science in Public

The study of representations of and about science, as mediated to and from the public, and as reflectively taken up by various publics, asks, What can we learn about science, and science in public, from examining the accessible points of intersection? The approach recognizes that the type of science knowledge that matters is largely contextual. Allowing inherent sense in all perspectives, this body of research examines social representations of science in cultural artifacts and awarenesses of science in the perceptions held by particular publics. The task is a formidable one—made complex by a public that "is far from monolithic in how it is likely to acquire and apply knowledge about science" (Nisbett, 2005b, Conclusion section).

Controversy, Trust, and Entangled Encounters of Science and Public

By way of introduction, and to highlight the reported friction at the interface of science and society, I offer recent images from text media, television, and touring exhibits. These snapshots illustrate how science can seem to encroach upon sociallysedimented agreements and long-established senses of order in matters of religious authority, public education, personal health, public well-being, belief in the supernatural, moral values, and humankind's relationship to and within the environment.

Trust, Belief, and Legitimate Knowledge

A place for trust. Science historian, Michael Fortun, and physicist, Herbert Bernstein, preface their book, *Muddling Through: Pursuing Science and Truths in the 21st Century*, with the following perceptions—all of which speak to issues of trust.

> Few things are more unsettling than working in or observing the sciences today. Yesterday's truths are quickly forgotten, made obsolete by the truer truths just released. Medical breakthroughs soon show serious limitations or disturbing side-effects. The next cosmic discovery will cost taxpayers a billion dollars more than the previous one. Many scientists with great ideas see those ideas go unsupported or undeveloped, and they encounter a public that is often uninterested, ill-informed, or hostile. Urgent controversies over health, behavior, and environment resist consensus and often seem only to splinter into bitter disagreements *among* scientists. Nature seems not only more and more complex but also opaque and even downright ornery. And so the problems pile up, and distrust and disillusionment set in…. Making sense of these contradictions is perhaps the hardest challenge for democracy in the twenty-first century. (1998, pp. *ix*-*x*)

Though researchers in the public understanding of science increasingly reject a deficit model of science literacy this change in perception of understanding does not deny real deficiencies in the public's science knowledge and understanding (Miller, 2002). Contentiousness and tentativeness within and about new science can only couple with exponential science growth in exceedingly specialized fields, to make illiteracy, in most domains, an inevitable reality for all. Indeed, "for most of science most of the time we are all public" (Rose, 2002). But, if one's science literacy, or lack thereof, proves insufficient for judging science at its frontiers—where it is arguably most in need of stewardship—then what suffices in its stead?

Even in a consensus forum, the scientist contributes science and the citizen offers local knowledge. In such an exchange, trust and respect join critical analysis and skepticism in articulating contextual truths and guiding appropriate decision-making. Though that trust be two-way, the incomprehensibility of the details of highly specialized science, together with common misconceptions about the nature of science, may make it seem more of a blind trust from the citizen's perspective. "It is a feature of the separation of science from the public sphere—a separation which is both social and cognitive—that often the public's only choice is whether or not to trust the scientists" (Gregory & Miller, 1998, p. 101).

Thus, regardless of what the citizen understands about science content and particular methods, the perceived trustworthiness of science remains of primal concern. It is here that public images of science weave an all-important backdrop to particular public encounters with science and scientists. The scientific community would desire that these images represent *well* that which science sees itself to be. By well, I mean that science be represented both accurately and in good light. After all, funding for research ultimately derives from public coffers, and if, as researcher, one believes in the value of one's work, surely one would wish others to share that view. On the other hand, should scientific propositions prove too strange, a hypothetical public, might react on fear of the unfamiliar by withholding funds and restricting actions. Conversely, if trust is high, as may be given to mythical figures and demagogues, that same public, trusting in science's wisdom, might eagerly disburden itself of any relevant social and ethical responsibility. Public reaction turns on its image of science, scientists, and the implicated and culturally-situated scientific community.

What would be the consequence if people understood scientists as typical humans, with all the usual human frailties, and that they are given to working in bureaucracies with a high priority for production and short-term gain? Moreover, what would happen to public trust, if it was also understood that unfettered, "pure" explorations of scientists could lead to technologies capable of changing matter to energy (and decimating whole populations), curing and causing plagues, "seeing" back to an ungodly origin of the universe, attributing natural design to chance, traveling to and transmitting pictures from distant planets, and using viruses to modify genetic codes, thus altering life as we know it? Under such conditions, how reasonable is it to allot more than normal trust in the integrity, foresight, and power of scientists to choose well for humankind?

Ipsos-Reid reports that Canadians trust firefighters medical professionals, and airline pilots above other occupations. But "then again, these are people we very much *want* to trust, aren't they?" (Bricker & Wright, 2005, p. 45) How much have we trusted science because we saw no other viable option? With the growing popularity of alternative ways of knowing, is this state of affairs changing?

Bauer, Petkova, & Boyadjieva (2000) affirm that "the image of science that people have may be more important than the facts and methods they know in building trust in science as an institution" (p. 32). That we do continue to trust at all, speaks to the power of science and the power of images. How these two are negotiated in the current century is all-important.

The nature and logical necessity of belief. Buckman offers a practical definition of belief as "any set of perceptions sustained by a person as a consistent attitude or view that extend beyond any factual information available, or even persist contrary to relevant factual information" (p. 11). Trust is "a firm belief in the honesty, truthfulness, justice, or power of a person or thing; faith" (Avis, Drysdale, Gregg, Neufeldt, & Scargill, 1983, p. 1205). These two, trust and belief, fill the spaces "of absence or invisibility. If things are transparent to us, we do not need trust" (Gregory & Miller, 1998, p. 101).

For thousands of years much of our world has remained opaque to understanding. In these conditions, “myths and religions have sustained us with stories of meaningful patterns—of gods and God, of supernatural beings and mystical forces, of the relationship between humans with other humans and their creators, and of our place in the cosmos” (Shermer, 1997, p. xxii). We prefer these fabrications to the discomfort of that which is uncertain and unpredictable. Cross-cultural anthropological research tells us “that most individual humans, and all human cultures, are content with the *illusion* of meaning” (Lett, 1992, p. 385)—with belief.

Toumey (1996) speaks of an Old Testament view of science—one that, like religion, combines respect *without* comprehension. In his study of apprentices at the Sellafield power station, Brian Wynne found that respect without comprehension was necessary to the smooth and efficient running of the nuclear plant (Gregory & Miller, 1998). The workers had minimal understanding "about the physics of nuclear power generation and its risks: they did not need to be [knowledgeable] for they trusted their employers and colleagues…. Not only that, but had they asked questions…they would have jeopardized the trust relationships" (p. 101).

At a basic human level, trust works with habituation and sensitization[9]—those adaptive features that enable selective attention to items of greatest relevance and immediacy (Davis, Sumara, & Luce-Kapler, 2000). We daily operate at the periphery of a core of deeply held and trusted beliefs (Hare, 2003). New information, whether encountered at school, through the media, in social settings, or on the Internet is interpreted and experienced in the context of these existing beliefs. Our efficient brains cull infrequently-accessed bits of information, but leave as resilient beliefs, the conclusions such bits were given to support (Bransford, Brown, & Cocking, 2000; Davis, Sumara, & Luce-Kapler, 2000). Accordingly, we should expect that people will forget those scientific knowns, studied in their school years, but rarely tapped in later years. As the details fade, our pattern- and meaning-seeking brains (Bransford,

[9] Habituation is the process of decreased conscious attention to a task because of its repetitive, predictable features. In habituation the brain streamlines neural networks by pruning unnecessary pathways. By physiologically accommodating to regularity and the predictability of situations and outcomes, we are able to divert attention elsewhere, trusting in automatic responses to take care of business. On the other hand, sensitization invokes neural proliferation and heightened attention to triggers that signal situations and outcomes that we cannot predict. Sensitization is the physiologically intensive response to an absence of trust.

Brown, & Cocking, 2000; Lett, 1992; Shermer, 1997) take the signs and symbols of science and fill in the gaps to create generalized impressions or images. These images form the foundation for attitudes, beliefs, and experiences of science—a template against which future claims made in the name of and about science can be measured (Nisbett, 2005a).

> It is actually past experience that enables…[individuals] to build forms, construct concepts and connect the diversity confronting them with schemata or frameworks already present in their minds (Higgins and Bargh, 1987)…. Schemata, scripts and prototypes…. all provide a stock of learned behaviour or ideas with which to face the needs of daily life. These categorizations… reformulate…the process of categorization or stereotyping (Billig, 1986). (Moscovici, 1988, p. 243)

However, as Serge Moscovici (1988, p. 243) asserts, we must be mindful to move through these information theories and enfold them into what we know about the reflexive nature of individual and social development. Consonant with a view from complexity science that re-emphasizes the co-construction of individual and collective knowledge, Moscovici reminds us, “all representations are both a resultant and a dissemination focus of what has been created” (p. 243). Hence, we again find reason to study public images of science. These particular social representations are the readily accessible artifacts, themselves instantaneous derivatives on the reflexively evolving curve of public and private perceptions and conceptions about science. In the absence of direct knowledge—of absolute scientific literacy, it is image that both reflects and dictates degrees of trust and trustworthiness.

In complex societies—dependent on the coordination of multiple, interrelated institutions, together with their corresponding divisions of labour and various specializations—no amount of personally attainable scientific literacy can sufficiently substitute for the central role of trust and the accompanying legitimation of institutional lore (Berger & Luckman, 1967). Yet, the removal of science making from public spaces into segregated areas enables the valuable accumulation of expertise with minimum hindrance. It is the price paid for smooth functioning of science and subsequent proliferation of goods. Steven Shapin comments, "only a fool would want to tear down the walls comfortably housing a goose laying so many golden eggs" (1992, p. 28).

Indeed? It may be wise to be so foolish. From the public's perspective, the golden eggs, though shiny and marketable, often disappoint with their impotence and occasional toxicity that leaves citizens hungry or sick for the edible natural sort. At such times, citizens become suspicious of scientific work in rooms walled up with words and ideas that they do not understand. They wonder too about the institutions—be they private enterprise or publicly funded—erecting the walls and conversing with the scientists. What would be the effect if scientific research forfeited some efficiency and the scientific community more regularly dispensed with interlocutors in favour of speaking in a common language built together with citizens? Could such a shift ever be practically approached? What "progress" could be lost and what trust could be gained from negotiated objectives and mutually developed understanding of motivations and limitations?

Attitudes toward science. As science grows more inaccessible to citizens, the opportunities to distrust increase. Between 1989 and 1995 the National Science Literacy Surveys charted subtle but rising Canadian distrust of science and technology from 41 to 46 percent and in 1997, 50 percent of Canadians, agreed that science made life change too fast (Burka, 1997). The respective 2001 figures for Europe and the United States were 61 and 38 percent (National Science Board [NSB], 2004), which put Canadian perceptions somewhere at about the mean of comparable Western nations.

Though 46 percent of Canadians polled in 1997 felt that, “because of their knowledge, researchers have power that makes them dangerous" (Burka, 1997, p. 1040), studies elsewhere indicate that people are generally willing, to a degree, to trust scientists with that power. In a 2003 New York State poll, participants tended to slightly agree[10] with the statement, “it is important for scientists to get research done even if they displease people by doing it” (Besley & Shanahan, 2005, p. 363). In the United States, agreement that “the benefits of scientific research outweigh any harmful results” (NSB, 2004, p. 7-23) has held sway at just over 70 percent since 1988. At the same time, American’s prefer scientists to stay clear of ethical issues, likely trusting them less in these realms. In 2003, 63 percent of respondents felt that scientific research did “not pay enough attention to the moral values of society” (pp. 7-23 to 7-24).

In contrast, Europeans agree less that science’s benefits outweigh its risks with support falling from 61 percent in 1992 to 50 percent in 2001 (p. 7-24). At the

[10] Mean score of 6.29 (SD=2.78) on a 10-point scale, where 10 is completely agree.

same time, Europeans are *more* likely to support increased government spending on research (p. 7-25).

Attitudes toward the delivery and uptake of science information are characterized by both a desire for unambiguous scientific directives and the freedom to choose to ignore these. In 2002, 86 percent of Canadian parents, guardian and other caregivers polled said they were overwhelmed by the amount of information on children's health that is available and 46 percent complained that the information was inconsistent, conflicting, or out of date. Meanwhile, though 93 percent of Canadians knew that car exhaust affects air quality, only two percent were prepared to use their own vehicle less (Campbell, 2002).

Ipsos-Reid polls (Bricker & Wright, 2005) have measured degree of trust in various industries and vocations. Canadians rank medical research as the top most-trusted industry. Of the 29 industries considered, those polled placed drug and pharmaceutical in fourth place, technology in ninth, and the chemical industry at 26, just before advertising, oil, and tobacco. That the chemical industry is ranked so close to the bottom and drug and pharmacology close to the top (both essentially dealing with chemicals) is commentary on the power of images—family doctor and caregiver of medicines contrasts against the mad scientist working with chemicals to concoct synthetic, non-natural, and therefore dangerous materials.

Of vocations, Bricker & Wright, (2005) report firefighters, pharmacists, nurses, and doctors, in that order, as most trustworthy. Chiropractors ranked 15th, two spots below the judicial system and environmentalists were 17th just two places ahead of religious figures. Politicians were rock bottom among the 31 vocations named. In a parallel list measuring distrust or “most likely to lie”, politicians topped the list, followed by lawyers, corporate executives, and union leaders. Amazingly, “more Canadians believe in the Loch Ness monster than believe in their politicians” (p. 52).

In the General Social Survey, conducted every year since 1973, American confidence in the leadership of the science community has remained second to medicine and, on three occasions, third to the military at 40 percent of respondents expressing a great deal of confidence. Although confidence in the medical profession has held the top spot for most years, those rates are down 15 to 20 percent from the high of 60 percent in 1974 (NSB, 2004, p. 7-33). Likewise, in ratings for prestige, scientists and doctors have consistently enjoyed the top two American spots over the years surveyed (1997 to 2002) by the Harris Poll (NSB, p. 7-33).

In comparison to the 1992 Eurobarometer, the 2001 version showed little change in public scientific knowledge. As in Canada and the U.S., Europeans express highest regard for doctors and scientists as against other professions and the “overall view of science also remains positive” (Eurobarometer 55.2, 2001, p. 6). At the same time, “science and technology are no longer considered a panacea for a series of problems.” (p. 7) Across all demographic groups there is widespread desire for some social control of science.

People turn to television and the media for their scientific knowledge, yet according to public polls, media and journalists engender less trust than scientists. In the U. S., public trust in the leadership role of the press dropped over 15 percentage points from 1974 to 1994 and since then has hovered about a low of ten percent (NSB, 2004, p. 7-32). In Canada, trust in journalists ranks just above trust in lawyers, at 31 percent, compared to 87 percent trust for nurses and 85 percent for doctors. Given a general distrust of journalists, it might be fair to ask, of what people read in the media, how much science do they believe?

Despite rising concerns surrounding anti-science sentiments, science and scientists do, nonetheless, enjoy a relatively high degree of public support. In 2001, 81 percent of Americans surveyed and 75 percent of Europeans surveyed agreed that, “even if it brings no immediate benefits, scientific research that advances the frontiers of knowledge is necessary and should be supported by the Federal government” (NSB, 2004, p. 7-4). Data from comparative studies confirm similar support among Canadians (J. Miller, Pardo, and Niwa, 1997). That said, the profile of trust in science is complex and contextual. For example, although the 1992 Eurobarometer indicated public support for science research in general, in the context of research involving animals, an earlier Gallup poll “showed that the public saw scientists as basically untrustworthy people” (Bodmer & Wilkins, 1992, p. 8).

Not surprisingly, an in-depth analysis of the 1989 Eurobarometer survey (Bauer, Durant, & Evans, 1994) revealed a moderate positive correlation between overall factual scientific knowledge and interest and attitudes to science. However, three findings of particular interest are worth repeating: (a) that with increased national levels of knowledge, both support and interest in science tends to polarize; (b) that “knowledge, interest in, and attitudes to science show a curvilinear relationship with levels of industrialization”; and (c) that the consistency of knowledge and attitude measures declines with increased national levels of knowledge, “suggesting a knowledge-ignorance paradox and knowledge specialization among informed populations". This analysis parallels a time-lapsed picture of changing attitudes toward science as countries become increasingly developed. It would appear that Western nations are in the throes of a downturn on the curvilinear relationship.

J. Miller, Pardo, and Niwa (1997) conducted a comparative analysis of national surveys in Europe, the United States, Japan, and Canada, and isolated two attitudinal schema operating across all four societies. These they termed: (a) public belief in the "promise of science and technology [S&T]" and (b) public "reservations about science and technology" (p. 95). Whereas the first schema clustered elements of trust in science's potential to ease living circumstances (in terms of health and material comfort), the second addressed skepticism about the speed of change, decreased dependence on faith, and the danger of scientific power. These schema were measured against several other variables including demographic data, civic scientific literacy, attentiveness to S&T policy, and approval for government funding of S&T research.

Data from all four societies revealed a trend that associated education, male gender, science literacy, and attentiveness/interest in S&T policy with higher beliefs in the promise of science (p. 97), less skepticism about science (p. 99), and greater support for government spending on S&T research (p. 101). However, these associations were not always significant and there were considerable differences in patterns from one society (and year of study) to the next. Controlling for other variables the following relationships reached levels of statistical significance as indicated.

In Canada, in 1989, women and individuals with high reservations about science were least likely to support government spending on science (R^2 = –.45 & –.25, respectively). People with high reservations about science also tended to believe less in its promise (R^2 = –.59).

As with the Canadians, Japanese women, in 1991, were less likely than males to support science research (R^2 = –.54). Meanwhile, and oddly enough, both individuals who believed in science's potential, as well as those with high reservations about science, tended to support government funding of S&T research (R^2 = .46 & .42, respectively). The researchers attribute this seeming contradiction to a high degree of uncritical support for science in post-war Japan and a low degree of salience for S&T issues in general (p. 102).

In the European Union, in 1992, attentiveness to S&T policy and belief in the promise of science were the highest predictors of support for S&T research (R^2 = .38 & .56, respectively). At the same time, science reservation was both unrelated to belief in the promise of science and unrelated to support for government funding of S&T research. The authors compare the European attitude toward science to that of a person who, uncomfortable flying in planes, but recognizing their convenience, flies in them anyway.

In the United States, in 1995, the authors found the strongest effect of education and science literacy on support for government funding of S&T research (R^2 = .39 & .44, respectively). As in Canada, individuals with high reservations about science were less inclined to believe in its promise (R^2 = –.64). And, as might be expected, the lower the reservations, and the higher the belief in promise, the more a person was willing to support government funding of S&T research (R^2 = –.42 & .49, respectively).

Collectively the factors studied by J. Miller, Pardo, & Niwa accounted for 30, 49, 51, and 63 percent of the variance in degree of support for government S&T funding in Canada, Europe, Japan, and the United States, respectively. What are the other unaccounted for factors? Perhaps in measuring attitude, this sort of research limits study to intermediate variables—those further removed from the question. One's attitude toward an entity is inextricably tied to one's image of all that it entails; that is, what one understands it to be. Quite possibly, the images assigned to science and ascribed to by various publics could hold a great deal of explanatory power in terms of attitudes and support.

In considering attitudes toward science, the issue can be clouded by images that associate science with other more- or less-trusted entities. Overall, the picture emerging from public polls has Canadians, Americans, and Europeans generally mistrusting individuals in powerful political and economic positions (NSB, 2004, chap. 7). Considering that, in funding and regulation, science is heavily associated with government or industry, it's begs the question that science is trusted at all. Perhaps a clue lies in the pattern of European public opinions surrounding BSE. While about half (51%) thought scientists bore "a great deal of responsibility," the brunt of the blame went to the agri-food industry (74%), politicians (69%), and farmers (69%) (European Commission 2001 in NSB, 2002, p. 7-27). Perhaps when science is implicated in a chain of events, its research, often furthest removed from ultimate effects, is more readily freed of responsibility for negative outcomes[11].

Still, how does science maintain this relative sacrosanct position of favour? What role do images play in maintaining a scientific mystique that leaves scientists somewhat untouched by unfortunate consequences and applications of their work? How do self-elevating images of science compare against the tentative and fallible natures of science arising out of philosophy, history, and sociology studies? And most important, what would ensue if science's iconic images were systematically dissembled in favour of more authentic representation?

Instances of Science in Public

Science versus creation worldviews. In Alberta, a Saturday special on page three of the Medicine Hat News (Karbashewski, 2002) exemplifies Locke's analysis of the creationist's worldview that rejects science's biology-theology dichotomy and takes the premise of a single God, creator of a single world including all elements, natural (scientific) and moral (religious) alike (Locke, 2002). The news article features a full-page spread, picturing Larry Dye the Creation Guy in a space suit, with a caption reading "Creationist Larry Dye is showing flaws in scientific theories of evolution" (p. A3). Using the vocabulary of science and the style of Bill Nye the Science Guy, Dye, a director with the local astronomy club, explains how a water canopy, like the gaseous canopies on Saturn and Jupiter, "helped create a greenhouse

[11] For an insightful discussion on the moral responsibility of scientists toward the ultimate applications of their work, see John Forge's (2000) essay, "Social and Moral Responsibility: An Outline." in Cross & Fensham (2000), pp. 61-71.

effect… and increased atmospheric pressure which provided enough oxygen. When it burst, it caused the flood” (p. A3).

In contrast to the above creationist’s approach that places science in the service of religion, the evolutionist denies any compatibility between science and the Bible (Locke, 2002) and, listing the essential features of science (especially in the American Association for the Advancement of Science [AAAS], 2002), outlines how, in failing to meet these characteristics, creation-science is both a misnomer and a science imposter—in short, pseudoscience (as in Coker, 2001 & Shermer, 1997, chap. 11). Defenders of science charge that such charlatans abscond its language and symbols to advance incommensurable ways of knowing (as in Bartholomew & Radford, 2003; Sagan, 1996; Schick & Vaughn, 2002; Scott, E. C., 1996; Shermer, 1997; & Toumey, C. P., 1996)—this, while forging an economy on alternative products, services, and technologies. In general, self-appointed science defenders argue for the clear demarcation and maintenance of boundaries between science and its “competitors” (Locke, 2002)—in the above case, religion (as in Haack, 2003; Humphrey, 1996; & Kurtz, 2003).

The tension between science and religion is no less evident than in the United States where, despite a fundamental legal tenet separating church and state, heated battles are waged across the nation (at the current time of writing at issue in 19 states), and gain public endorsement by no less than president Bush (Neuman, 2005), over the exclusion in schools of creationism and intelligent design as viable scientific alternatives to evolution. Accusations and warnings rage on either side of these debates. Scientists and educators, alarmed at the growing trend, see a “masked effort to replace science with theology", while Christian activists claim persecution at the hands of a particular brand of scientists (Slevin, 2005, p. A01).

The framework of the creation-evolution debate is typical of what cultural anthropologist, Christopher Toumey (1996) describes as a "pseudosymmetry" of debates about issues that are considered non-controversial by the scientific community. By pitting select representative scientists against a few maverick ones, these debates image a symmetrical structure on either side. In this way, "a few dissenting scientists, if they are willing to speak out…[gain] a political impact much larger than is suggested by their isolated position" (Brian Martin as cited on p. 77). The situation is exacerbated by an altruistic media that, in the interest of fair play,

> typically present a scientific dispute as a two-sided matter by giving both sides approximately equal time or space….[This] leads to a systematic distortion of scientific authority when one scientist representing a small faction of dissidents or insurgents receives as much media attention as another scientist representing the majority of experts in that field, for equal time makes it *seem* that the scientific community is about equally divided when it is not. (Toumey, 1996, p. 155)

According to Gregory and Miller (1998), the problem is compounded because the public, being sympathetic to the lone outsider, is "more likely to believe a maverick…. and so the fact that a prediction is declared unscientific is unlikely to make much difference to its credibility" (p. 126).

Science & human values: Biotechnology & posed cadavers. Religion and science education are not the sole contentious sites of intersection between science and the public. Adjusting to a world configured and re-configured, at an every-increasing pace, by scientific and technological research, strains public trust in a future ironically rendered less predictable because of the scientific community's ingenuity. Biotechnology, fraught with claims, counterclaims, and ambiguity in public, is a hotbed for friction between embracers of innovation eager to figure the technological products of science into economic equations, and voices of caution, leery of the new, strange, unnatural, and potentially dangerous uncertainties of science's creations. Inherent risks and benefits intersect uncomfortably with human values when "science plays God" in altering life forms as in cloning, embryonics, xenotransplants, and genetically modified organisms. Conflicting policies and perspectives should come as no surprise. In 2005, while environment ministers of the European Union [EU] upheld eight national bans on genetically modified crops, the United States, Canada and Argentina continued a lawsuit in the World Trade Organization alleging that the EU's biotechnology policy "harms trade and is not founded on science" (EU ban on GMOs, p. B8).

New technologies also impact the very media of communication and presentation of scientific knowledge. For example, devising and using a new process of plastination, which substitutes polymers for water and fat in tissues and organs of deceased humans, anatomy professor Gunther von Hagens' created *Bodyworlds: The anatomical exhibition of real human bodies* (n.d.). Von Hagen, deemed a modern-day Frankenstein by some, sees his work as continuing "the scientific tradition whose recurring theme is that research should serve the general enlightenment" (von Hagen in The naked and the dead, 2002, ¶15). Although the collection of posed cadavers remains a constant from venue to venue, that which it represents varies according to individual contexts brought to the work—so much that it is at once described as a "gorgeous meeting of the scientific and the poetic" (Bjork, 2001, in von Hagen, Celebrity comments section) and "one of the most objectionable and shameful proposals I have ever seen" (MP Sir Teddy Taylor, in MPs condemn show, 2002, Entertainment Arts section). We would do well to attend to the human values underlying these varied reactions and to consider systematically and deeply their meanings and implication. Alan Leshner, CEO of AAAS, advises a much more inclusive approach to shaping scientific research—one that engages communities other than the scientific community in assertively discussing the meaning and usefulness of science and scientific progress (2005, p. 815).

Privileged science: incontrovertible evidence in forensics (CSI) & the non-science underdog (X-Files). Popular television shows and successful advertisements tap a public pulse. "Advertising [and arguably popular entertaining in general] really does reflect popular culture…. It's not the leader of the pack" (O'Reilly, 2005). *The X-files*, featuring paranormal[12] phenomena and populist conspiracy theories, held television audiences captive through a ten-year run that contrasted a scientific/skeptical perspective (agent Scully) against a paranormal/conspiracy point of view (agent Mulder) —"and week after week, the skeptical perspective always lost" (Goode, September/October 2002, ¶ 4). According to creator Chris Carter, the show's scientific content was rigorously researched. Yet, as dramatic fiction, its first

[12] "The term 'paranormal' refers to phenomena that allegedly cannot be accounted for or explained in terms of normal science and that thus transcend the limits of a naturalistic framework" (Kurtz, 1996, p. 494).

priority was to entertain and “a rather plausible and rational and ultimately mundane answer for these things [paranormal events] turned out to be a disappointing kind of storytelling” (Carter as cited in Trull, 1997, ¶18). For the 20 percent of Canadians who “believe that extraterrestrials visit the earth on a ‘regular basis’” (Bricker & Wright, 2005, p. 52) the fine line between fiction and non-fiction is likely less clear.

Similarly, the television series, *Crime Scene Investigation [CSI]* offers a melding of fact and fiction in its storied presentation of forensic science. The public, both fascinated and schooled by the demonstrated objectivity and accuracy of science, transposes its newfound understanding to the nature of forensic science in real life—so much that *CSI* is purported to have at times raised, to unattainable heights, jurors’ expectations for conclusive evidence from science in criminal convictions (Blake verdict and ‘CSI effect’, 2005). Thus, while science curricula in western cultures increasingly emphasize instruction in the nature of science (McComas & Olson, 1998), television reflects and refracts alternative images about science’s nature.

According to sociologist Erich Goode, *The X-Files*, blended fact and fiction in a way that appealed to the underdog’s desire to dethrone science from its privileged place of seeming objective omniscience if not omnipotence.

> Most varieties of populism see science as symbolizing or representing elites—that is, as contrary to the views and the interests of the common man and woman. Science is complicated and difficult to learn and superficially it seems to be monopolized by, and to support the interest of, the powers that be. (¶7)

> In the paranormal conspiracy theory, the underdog tries to reveal the truth about scientifically unexplainable phenomena…, thereby empowering the public. The underdog is opposed to a ‘rigid scientific view of the world.’ In place of this rigid view, the anti-conspiracy theory favors intuition, what feels right, what seems right, experience, memory—in short, what contradicts or can’t be explained by science. (¶10)

Anthropologist, James Lett asserts, “no amount of training in evidential reasoning will be sufficient to dissuade most people from beliefs to which they have a strong emotional commitment” (1992, p. 387). And people do carry strong emotional commitment to their “intuition, what feels right, what seems right, experience, [and] memory”.

Popularization and anti-science sentiment. An April 9, 2005 *Globe and Mail* Focus story (Abraham), headlining “No Faith in Science,” looks at science and the control of information. Medical journalist, Carolyn Abraham implicates religion, ideology, and “public disenchantment with science” for an American political climate where, as one researcher put it, “propaganda has taken precedence over science” (p. F9). She observes that, when research findings call for actions that clash with moral beliefs or economic edicts (as in the cases of teen sexuality and disease control, in one context, and environmental degradation, to name another), scientists increasingly report their work suppressed and their messages either distorted or discounted in a “style of ‘governance and the application of power’ [that] clashes with scientific culture” (David Guston as cited on p. F9). In response, alarmed “scientists are stepping down from their ivory towers to defend their work and, more significantly, to win public support" (p. F9).

"The attitude of the scientific community toward popularization has varied widely and dramatically, both over time and between disciplines" (Gregory & Miller, S., 1998, p. 81). According to Gregory and Miller, scientific communities generally responded to the rise of the "public understanding of science" movements of the 1980s with a greater acceptance of scientist-popularizers (Gregory & Miller, S., 1998)—visible scientists the likes of David Suzuki, Stephen Hawkings, Carl Sagan, and Stephen Gould. As previous stigmas lessen, scientists (and others who would use science in advancing their particular agendas) increasingly value popularization as an "act of persuasion" (p. 85)—where science can define and distinguish itself to the public. "The last two decades have seen an extraordinary upsurge in popular science book publishing" (Rose, 2003, p. 307). However, Gregory and Miller (1998) assert, "the changing motives of popularizers and the oscillating attitudes of the scientific community have left a legacy of confusion and ambivalence" (p. 82). For example, though popularization has "made claims for the privileged status of science…[it] has also been suppressed in order to maintain science's privileged status. Popularization exaggerates and highlights tensions in the scientific self-image: science is neutral but concerned, commonsense but special, democratic but authoritative" (p. 82). Unsurprisingly, incongruencies across multiple oversimplified images of science have often done more to confuse and alienate than to clarify any nature of science or to enamour members of the public to the scientific community. Indeed, if images of science in public places tell us anything, they should speak to a science larger and more diverse and complex than any single representation could ever hope to hold (Lewenstein, 2002).

Re-imaging fraudulence to preserve trust. A July 10, 2005 Associated Press article, reporting on the demise due to fraudulent conduct of Dr. Andrew Friedman, describes him as a "brilliant surgeon and researcher" (Mendoza). Last year, the "Department of Health and Human Services [in the U.S.] received 274 complaints" of science misconduct. Mendoza reports that this is likely "a small fraction of all the incidents of fabrication, falsification and plagiarism." If this is true, then, that we trust science at all seems an attestation either to the power of awe and indoctrination or to wishful thinking.

In *Selling Science* (1995), Dorothy Nelkin notes how distanced and lofty images of incomprehensible science and scientists serve to maintain a mystique of superiority that is "useful for a community seeking public funds with limited public accountability" (pp. 14-15). Fraudulent acts in most fields evoke journalistic descriptions of corruption, abuses of trust, and consumer "ripoff." But, as Nelkin observes, "when a scientist succumbs to temptation and pays the price, it is always sad" (p. 29). And so, it is not lack of integrity but rather "mental disorder; inadequate mentoring; and, most commonly tremendous and increasing professional pressure to publish studies" (David Wright, as cited in Mendoza) that explains why scientists cheat. In short, according to these writers, it is not the altruistic scientist that disappoints us, but rather the unfortunate scientist who has fallen victim to unreasonable demands.

Scientific Literacy Reconsidered

To know science is to love it—or is it? Since the late 50s when formal measures of public science literacy came into vogue (Lederman, Wade, & Bell, 1998; Miller, J. D., 1998; Sturgis & Allum, 2004), a belief that "to know science is to love it" underpinned campaigns to improve support for the scientific community by ameliorating public science literacy (Committee for the Public Understanding of Science [CoPUS], 1996). While some research suggests a positive relationship between science education, factual science knowledge, and public support for science (notably among Americans but less so in Canada, Japan, and Europe, see Miller, J. D., Pardo, & Niwa, 1997) those examining the relationship more closely report that "the scientifically informed are more discriminating in their judgements" both for and against varying kinds of research (Evans and Durant in CoPUS, 1996, ¶10). Furthermore, when the approach for engaging the public in matters scientific restricts itself, as has been the tendency (Hurd, 1997; Lewenstein, 2002; Sturgis & Allum, 2004; Toumey, 1996), to self-defense and a sales pitch for graduating more students into science while ensuring license to carry on as usual, then the project has proven ineffective from the start.

University students mirror their high school counterparts in seemingly unfounded self-confidence for interpreting science in the media. Typical interpretive errors include "certainty bias…regarding truth status, confused cause and correlation, and…difficulty distinguishing explanations of phenomena from the phenomena themselves" (Norris, Phillips, & Korpan, 2003, p. 123). Consistent with studies in other first world nations, a picture of not less than 75 percent science illiteracy in the

UK (Miller, J. D. 1998), as measured by criteria set by researchers predominantly from the hard sciences, has remained stubbornly unresponsive "to the best efforts of government and educators alike to popularize science and make it more accessible to ordinary citizens" (Sturgis & Allum, 2004, p. 56).

Educating the public. The life of CoPus, a committee that brought together the Royal Society, the British Association for the Advancement of Science and the Royal Institution, "to promote public understanding and appreciation of matters scientific" (Miller, S., 2001, p. 116), illustrates the difficulty, and possible futility, of an approach (as described by Bodmer & Wilkins, 1992) that seeks to educate by disseminating, in appealing and entertaining ways, "essential" science knowledge to the public. As Steve Miller reports, after ten years of smoothly run programs, a 1996 follow-up survey "indicated little change in scientific literacy" (p. 116). These findings in "free-choice" education—that is, education outside formal schooling—parallel repeated efforts to ameliorate science schooling.

Over the past half-century, governments have teamed with scientists, educators, and curricularists to improve support for scientific research by ameliorating science education in schools. The approaches taken have varied with the times. On the heels of the technological triumphs of World War II and spurred by Russia's preemptive 1957 Sputnik launch, the late 50s saw an era of "new math," more school science for all students and greater rigour in that science (Hurd, 1997). When this raising of the bar backfired by instead fostering student disinterest in science, the curricula of the late 60s and early 70s sought to deliver a science for all students by emphasizing hands-on activities. When the experiential approach failed to procure the desired results, curricularists reasoned that student learning suffered from cookbook re-enactments of the so-called scientific method. Consequently, the 80s saw new efforts to transform laboratory exercises into truer-to-science inquiry. In practice however, teaching understanding through inquiry was, and continues to be, compromised by overstuffed curricula (Mrazek & Howes, 2004), an ensconced tradition of schools designed after a factory model of mass production (one ill-suited to developing the critical thinking skills thought fundamental to inquiry), and a complement of teachers, themselves products of the system and thus sharing many public misconceptions about science and science inquiry.

As the millennium approached, growing realization of a lack of science specialists teachers led to programs both for encouraging teachers into science specializations and for developing existing teachers' understandings in science (see, for e.g., Financial incentives, 2005; Feller, 2005). This too proved no easy fix. For mathematically- and scientifically-inclined individuals, teaching could not have the same appeal as more lucrative careers elsewhere. For those teachers lacking a science bent, much less a science specialization, one-stop workshops were inadequate solutions.

While current strategies have not abandoned professional development initiatives, these efforts are now supplemented by increasing emphases on the history, philosophy, and general nature of science [NOS], both as curricular content and in teacher preparation (Lederman, 2003a; McComas et al., 1998). Yet, for reasons presented below, teaching the nature of science is itself fraught with potential difficulty (Abd-El-Khalick, 2003; Bell, 2003).

It is reasonable to assume that, if schools deliver science as a collection of clear-cut irrefutable facts and theories proven through experimentation, then disillusionment can set in when new science, apprehended through the media, appears decidedly different. "Having been told that scientists possess a magic wand, the public may well react with cynicism to…entirely normal displays of contingency and uncertainty" (Shapin, 1992, p. 29). Indeed, "utopia becomes the subconscious enabler of cynicism" (Chrisopher Hitchens in Mole, 2004, p. 36). Judith Ramaley (2003) emphasizes that building a deep understanding of science is a matter of building a foundation for trust. "People who think that science is a product rather than a messy process of inquiry can become profoundly uncomfortable when they are brought face-to-face with the uncertainties and arguments at the frontiers of science" (p. 228).

Recent information acquired through scientific research speaks to and can potentially inform perspectives and decision-making on numerous contentious socioscientific issues from sexual practices, drug use, and health living to clean air and global warming[13]. Reactions to socioscientific data are varied and complex—especially when such data appear anomalous and forcing of revaluations of tacit

[13] Examples of contentious socioscientific issues—that is, issues where science can inform to greater or lesser degrees—include questions related to: morality and public health (e.g., AIDS prevention & teen sexual practices; drug drop-in centers that provide street drugs, xenotransplants, animal use in medical research); family practices and child-rearing (e.g., use of corporal punishment to build character); religious beliefs and human rights (e.g., legalization of gay marriage); physical, emotional, and spiritual wellness (e.g. drug/chemical therapy vs. herbal/natural remedies, spiritual healing, communication with the dead); diet (e.g., organic foods, fad diets, detoxification, & agri-food industrial practices involving for e.g., food labeling, genetically modified organisms [GMOs], & Bovine Spongiform Encephalitis [BSE or mad cow disease]); air quality (e.g., 2005 pesticide prohibitions for lawn care in Toronto), water quality (e.g., fluoridation, water use practices, & safety of bottled vs. tap water); and climate change (e.g., environmentally responsible action at individual and government policy levels).

assumptions and beliefs. In a climate of relative truths, where validity seems realm-dependent and menus of justifications are available, people are disinclined to attempt the daunting task of integrating or negotiating conflicting perspectives. Instead, the preference is to compartmentalize incompatible data (Abd-El-Khalick, 2003; Bell, 2003), and in particular, to deem scientific information less admissible or relevant when it comes to informing moral questions (Costa, 1995; Mole, 2004; Zeidler et al., 2002). For those individuals, whose past experiences with science have summoned feelings of confusion, incompetence, and helplessness, the thought of turning to “neutral”, “sterile” science to help resolve moral dilemmas seems especially counterproductive. Discomfort often occurs when people most want clear simple answers to personally relevant and emotionally charged questions. At such times, they are likely to “prefer the opinions of their friends or trusted advisors over the information provided by scientists, especially when scientists are [or are presented as being] deeply divided over an issue" (Ramaley, 2003, p. 228).

Contemporary literature on teacher preparation and the public schooling of NOS argues for a socioscientific context in the initial uptake of science. This approach to science education begins from a social context and is meant to explicitly and actively develop understanding of the nature of science in meaningful and relevant ways. Students consider how, both, non-contentious and frontier science can inform thinking and decision-making on larger than science issues. In this vision, students learn to be critical consumers of both new and established scientific information. In theory, a clearer understanding of the nature of science will develop as students grapple to judiciously apply scientific data in the context of debate about matters of social significance (Abd-El-Khalick, 2003; Aikenhead, 1985; Bell, 2003; Lee & Roth, 2003; Tytler, Duggan, & Gott, 2001; Roth & Désautel, 2004; Zeidler et al., 2002).

In the hopes of addressing underlying misrepresentations of science's nature in schools, more recent curricular documents emphasize the explicit and systematic teaching of NOS across all grades (McComas & Olson, 1998). Yet, science teachers—given to holding a rigid view of science as certain and infallible—are among those most likely to misunderstand science's complex and multifarious nature (Abd-El-Khalick, 2001; Ryan & Aikenhead, 1992). Moreover, efforts to reach consensus about NOS, and to render suitable content for students, creates the potential for misleading simplification and reduction. Both these difficulties came into play in a recent American study.

When Abd-El-Khalick (2001) trained pre-service elementary teachers on currently non-controversial aspects of NOS (Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003) as tentative, empirical, theory-laden, inferential, imaginative, and creative, these future teachers reacted with uneasiness and discomfort at "the notion that many ideas in science were not 'proven' or 'certain'" (Abd-El-Khalick, 2001, p. 227). In the face of perceived ambiguity in science, interviewees felt "confused" and "used". They wished science could be objective, and expressed a more generalized lack of "faith" in science. Consistent with the findings of previous studies of college students ("Perry, 1970, 1981" in Abd-El-Khalick), participants shifted from a "scientistic" view of "believing" in science to a "naïve relativistic" one that sees "scientific knowledge as 'someone's opinion about what is going on'" (p. 229).

Abd-El-Kalick suggests that the shift from scientism to naïve relativism may be a necessary precursor to successfully negotiating the tension between science's tentative nature and the idea that some claims are more valid and credible than others. That being the case, several questions remain: Will mistrust in science and naïve relativism emerge out of efforts to add nature of science understanding to scientific literacy? Indeed, as various academic representations about science's social nature have made their way into popular conception, have we not already witnessed growing anti-science sentiment? What broader epistemic views interact with NOS understanding to produce mistrust? What natures do current public images of science present? What is the synergistic effect of multiple images on public apprehension of and interaction with science?

Recognizing that "people can get very angry when their gods turn out to be human" (Shapin, 1992, p. 29) the scientific community needs to tread carefully in this desired path toward more honest and less contrived public representations of science's nature. Still, Shapin asserts, it is "sound instinct to trust the people with the truth–even if some work has also to be done to overcome institutionalized idealizations" (p. 29).

To this point in the present discussion, and inherent in efforts that target science literacy as the problem, is a perspective that interprets low scores on public scientific literacy tests—themselves evolved to include content, process, and nature of science (as according to criteria that established science feels the public should know)—as a serious threat to a thriving participatory democracy. This doomsday perspective can be crudely summarized by several assumptions: that those members of the scientific community who undertake the measurement of science literacy are in the know, that their critics and competitors are misguided, and that the failure to grasp the truths of, and about, science, as measured by science literacy assessments, endangers civilized life, as we know. It is logic that derives from a belief that, “science represents the safeguard of the race against these natural propensities [to “jump to conclusions” without full examination of evidence] and the evils which flow from them” (John Dewey, 1916, in Matthews, 1998, p. *xii*).

The history of reform efforts in science education attests to a problem often reduced to inadequate science literacy and considered solvable through properly managed and improved education. Thus, the implication goes, if students and their teachers learn the true NOS, they will be more understanding of publicized controversies in frontier science and more appreciative of established science (McComas et al., 1998; Mole, 2004; Van Dijck, 2003). Rachel Young summarizes the logic of this perspective: "The crux of the science literacy problem is that, without the tools to assess the merits of various claims of scientific truth, the public may be unable to distinguish revolutionary science from sheer quackery'" (in Ramaley, 2003, p. 229).

Susan Haack (2003) recognizes that science ought not function as privileged dictator of absolute and unquestionable truths. At the same time, she envisions a literate public able to recognize that, in those countless areas where science is sufficiently advanced and consistent, it serves as our most accurate spokesperson and translator of nature's imperatives and the current limits of human intervention. In general it is hoped that, when a literate public encounters discomforting reality as explained by science, they will appropriately resist the urge to haul established scientific givens back to the debate table (Cross & Fensham, 2000; Toumey, 1996).

By the same token, this shrewd public will be less likely to fall prey to the mischief of “conjured science,” as Toumey (1996) terms it. He describes conjured science as a tempting mélange of fabricated and palatable "truths", delivered with sensibility, confidence, and compassion, in a rhetoric that mixes science and folklore. Finding a reinforcing niche in the beliefs and hopes of unschooled citizens, this imposter can trump “real science” by offering accessible explanations and simple solutions to complex human problems—problems for which, the sanctioned scientific community insists, there are no simple solutions. By using "the common symbols and images of science" (Toumey, 1996, p. 8) to bestow plenary authority on distant and unrelated causes and ideologies, conjured science compounds the science literacy problem through further erosion of the very meaning, nature, and credibility of science. A sufficiently literate public, according to the deficit model, would resist this.

In short, the deficit approach argues that, by understanding the basics of science content, nature, and process, a better-educated, scientifically literate public will: (a) gain reasons for renewed faith in science; (b) make more choices consonant with established science; and (c) better recognize and discount the voices of charlatans.

The above explications outline the kinds of thinking and action that often follow from a deficit perspective of the public understanding of science. However, if fifty plus years of educational reform, sprung from the question, “How can we better transmit knowledge about science from expert to public?" has seen little positive effect, then perhaps we have been asking the wrong question. Increasingly, the literature rejects one-sided communication strategies bent on coercing or otherwise encouraging a passive public toward improved science literacy on the scientific community's terms. Instead, newer perspectives define effective communication and teaching as that which engages both expert and non-expert dialogically (Bransford, Brown, & Cocking, 2000). Two-way communication prioritizes the input of scientist and non-scientist alike in addressing specific, relevant, situated contexts, concerns, and interests (Cross & Fensham, 2000; Duschl & Hamilton, 1998; Fortun & Bernstein,1998; Gregory & Miller, 1998; Lee & Roth, 2003; Matthews, 1998).

In summarizing his arguments on *The Governance of Science,* sociologist Steve Fuller adamantly stated, "I reject 'science literacy' as a strategy for opening up science to the public: at best, it secures a receptive attitude without provision for greater public participation" (p. 176). In today's era of Big Science, Fuller advocates a return to the republican ideal where forums are provided "so that *all* professional knowledge producers can participate in determining the direction their fields take and the general public can influence the process in a manner that is commensurate to their interest in such matters" (p. 177).

A variety of scholarly writing—especially associated with the sociology of science, science education, and science communication—has, over the past decade, examined, documented, and explored new models for improving the relationship between science and the public. This body of literature, much of it published in the journal of *Public Understanding of Science,* has, "in dialectic with the 'deficit model,'" explored alternatives such as "contextual" and "lay knowledge" models (Lewenstein, 2002, p. 2). Indeed, this public understanding of science movement—termed a contextualist perspective by Sturgis & Allum (2004)—enjoys growing popularity, especially in Europe. Proponents argue that the central issue in people's understanding of science is less the ability to recall discrete facts (be they about sciences' content, processes, or nature) and more about "a keen appreciation of the places where science and technology articulate smoothly with one's experience of life… and of the trustworthiness of expert claims and institutions" (Jasanoff in Sturgis & Allum, 2004, p. 58).

In alternatives to the deficit model, scientists are re-imagined as humans, not super-humans, with particular expert knowledge to share and a desire to work collaboratively with citizens in deciding the direction that research, especially contentious research, ought to take. Keeping in mind the numerous situations where scientific agendas are not, in fact, the property of scientists to keep or share, but rather at the discretion of big business, I continue the exploration of an ideal collaborative model. In such a paradigm, scientists—recognized and accessed for the expert authority they bring to issues of social consequence—solicit the views of citizens to gain local and contextual knowledge that, in turn, guide the formulation of appropriate research questions. If only for lack of experience, such an approach entails "a more difficult task, but it is one that allows scientists and the public to work together as citizens of a scientific culture" (Gregory & Miller, 1998, p. 99).

In support of the collaborative approach, physicist and philosopher of science, Jean-Marc Lévy-Leblond (1992) rejects any ideal of absolute knowledge in favour of the reality of relative ignorance. In his view, we will not reintegrate science and technology with culture without first admitting, assessing, and confronting the limitations of our abilities to know. If a basic tenet of democratic societies is that "conscience should take precedence over competence" (p. 20), and if we do not require expert, nor even 'amateur' levels of knowledge in constitutional or criminal law before allowing citizens to use their voting rights or participate in a jury, then why, Lévy-Leblond asks, should we be more demanding concerning technical and scientific matters? In other words, the problem, from his perspective, is not so much a gap in science knowledge or science literacy that separates laypeople from scientists, but a power gap that puts scientific and technical developments outside of democratic control.

At this point, a proviso is in order. Although laudable in theory, in practice, advocating citizen-science collaborative forums to rectify power imbalances overlooks the current reality that the power gap separating scientific and technical developments from democratic control lies much less in the hands of scientists than in those of monopolistic corporations. It is highly unlikely that research in the public understanding of science will readily counterbalance profit motive in changing the way corporate boards or granting agencies (themselves often controlled by the sectional interests of corporate government) negotiate scientific research. Notwithstanding, the collaborative citizen-scientist model can make inroads of influence in both designing science curricula and setting government policy on scientific research.

The literature of the past decade in the public understanding of science increasingly features practical experiments in effectuating democratic science. These include "consensus conferences, in which a well-briefed but lay group of citizens evaluate new scientific issues and techniques" and need-to-know "science shops that issue information to concerned members of the general public for their specific and—usually—local use" (Miller, S., 2001, p. 117). In these formats (Einsiedel, 2002; Fortun & Bernstein, 1998; Lee & Roth, 2003; Roth & Désautels, 2004), and in select research classrooms (Aikenhead, 1985, 2000; Duschl, 2000), dialogical explorations about particular issues, set in relevant contexts, allow common-sense knowledge to merge with scientific perspective in guiding inquiry questions and future steps.

Pioneer work by science educator, Glen Aikenhead (2000), explores instructional strategies to facilitate and honour "cultural border crossings" (p. 256) between everyday citizen science, local science knowledge, and the western science of academia. In this way, schooling can strike a better "balance among several legitimate sciences important to students' cultural identity" (p. 261). For example, students attentively and respectfully negotiate their common sense knowledge of a sunrise against a western science model of the world turning. Likewise teachers and students carefully define science terms that cross borders in a manner that accepts multiple meanings according to context. Through this process, Aikenhead strives to "resolve the contradiction between a science-for-all goal for school science and the necessity that western science be the *only* science in 'science for all'" (p. 261).

As might be expected, there are those less receptive to changes, especially when such changes broach the order of paradigm shifts. In as much as these approaches engender an image of science quite different from the remote and esoteric variety that currently prevails, individuals—particularly (it could be argued) those enjoying the political advantages of such distance—may object on the grounds that collaboration result in a devolution of autonomy, power, and trust from informed science to uninformed public. Indeed, some authors warn (Holton, 2002; Jacobs, 2004) that lest we suffer the demise of western science for a return to medieval ways of knowing and being, we will at a minimum want to carefully hone and configure these collaborative undertakings.

In sum, while activities of the likes of CoPUS “legitimized science communication as a worthwhile and dutiful activity” (Miller, S., 2002, p. 118) for educating the public, a contextual approach, emphasizing reflexivity, finds its roots in re-conceptualizing the very notion of science literacy. That the “contextual approach” or at least something beyond a “public deficiency, science sufficiency” model has come of age (when it comes to honouring an informed public) is perhaps best indicated by pronouncements on either side of the Altantic. In the UK, Science Minister Lord Sainsbury spoke, as early as 1999, on the “demise of the deficit model” (in Miller, S., 2001, p. 117) and in the U.S., CEO of AAAS, Alan Leshner commenting that, “insanity is doing the same thing over and over and expecting a different outcome,” offers that scientists should “try some diplomacy and discussion and see how that goes for a change” (2005).

In areas where research broaches potentially contentious issues or where research yields knowledge and material products for public consumption, scientists—when given sufficient latitude to direct their inquiry questions—increasingly conceive their societal role as specialized collaborators that work with various publics in shaping the direction that science should take. In Canada, government and public research institutions move toward public consultation as a necessary part of decision-making. For example, in the environmental decision-making process, public consultation has taken three forms: co-management in the sharing of power and responsibility between governments and local resource users; national round table discussions; and public participation in environmental assessment (Statistics Canada, 2000, Section 7.5.3).

Of course, it is one thing to envisage a solution in the republican ideal of an open society; but yet another to realize it. Focus groups, discussion forums, and advisory panels cannot become political tools to placate one group while privileging another. For example, at the time of writing, “twenty-one Canadian environmental groups are boycotting a key advisory panel…saying they are being marginalized and business interests have been put in control” (Chase & Galloway, 2005, p. A4). For scientists to use collaboration in citizen-science groups to inform the direction of their research, they must first have the freedom of their own research choices. Instead, that liberty often rests with the benefactors and big business financing scientific investigations.

At best, scientists only partly own the inquiry questions they ask. Still, the sorts of questions asked, and the motivations for those questions (be they economic profit, political gain, public benefit, or pure inquiry) drive particular answers that can ultimately dictate to the very nature of our collective human condition. "Science itself cannot decide which uses to pursue, which not" (Howard Gardner, 2003, p. 163).

Indeed, most often it does not. Ultimately, humans and their collectives, acting through their available formal and informal capacities, make these decisions.

Conundrums and Competing Worldviews

From the research on public perceptions and attitudes toward science, a profile emerges of a public that trusts science in a generic sense. However, a background of uneasiness about science's unchecked power tempers that trust. When specific intersection points of science and public are teased out, trust becomes contextualized. According to the aforementioned surveys, people largely trust the healing sciences, they are less trusting of environmental sciences, and seem most skeptical about industrial sciences, especially those associated with "unnatural" substances.

It appears that, in as much as scientific work contributes safe applications that ease and commodify life in current times, people are content to trust in the certainty and awe of its explanatory and productive capacity. But trust in the knowledge and material products of science erodes: (a) as the risks and uncertainties of new science surface; (b) as science's products are experienced as artificial and a threat to the natural order; and (c) as scientific explanations are seen to supplant supernatural and moral one's.

On matters of risk and uncertainty, "it is a feature of a scientific and technological society that many of the risks we have to deal with are scientific and technological risks" (Gregory & Miller, 1998, p. 101). In regards science's works as uncomfortably unnatural, it becomes a question of degree of human tampering as there is very little left on the planet that qualifies as natural[14], leastwise in the sense of not artificial. Indeed, if science undertakes the study of the natural world and natural is mistakenly taken in the context of unaffected by humans, then, in a simplistic interpretation, science cannot study humans nor is there much left that is natural for science to study.

Clearly there is other meaning to science as the study of the natural world. That meaning calls for natural explanations to observable phenomenon. As a way of knowing, science deems supernatural explanations inadmissible because these exist outside science's legitimate realm of study—that realm being the natural world. From the beginning, science's explicit commitment to seeking natural explanations represented a conscious delimiting of study. It was never intended as an affront to supernatural explanations and belief systems (Gould, 2003). Indeed, in his historical accounting of the emergence of western science, Stephen Gould asserts, "I cannot emphasize too strongly that the old model of all-out warfare between science and

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[14] Here, adopting a popular meaning of natural as not artificial—a meaning that associates natural with something desirable and good (Coyle & Fairweather, 2005)—leads to a common misinterpretation of the proper subject of science as the natural or not artificial world, as opposed to the intended interpretation as the study of non-supernatural explanations for the world. The extent to which science moves away from its study of the natural world and into an artificially created world of synthetics and altered life forms is the extent to which science becomes less trustworthy. This view derives from an anthropocentric perspective that separates humans from the natural world in which we live. It presupposes our ability to disentangle ourselves from the world out there, when we are, in fact, inextricably intertwined and implicated in its ongoing co-construction. Indeed, if science would study the natural world, and if that natural world were construed as some virgin land free from prior human effects, then the objects of scientific study, at least on this planet, are largely extinct. Even, at the most basic of levels, that is, in the world of quantum mechanics, the uncertainty principle (loosely translated) dictates that the very act of observing and measuring matter will effect change in that matter. There can be no boundary between natural and unnatural, only gradations of human force imposed into a shared complex system of matter, energy, and life.

religion… represents an absurdly false and caricatured dichotomy that can only disrespect both supposed sides of this nonexistent conflict" (p. 29). In their study of science education, Ryan and Aikenhead (1992) present the scientific "assumption that the natural world can not be altered by a supernatural being (for example, a deity)" (Ryan & Aikenhead, 1992, p. 565). There is a fine line, often missed, between saying that science operates on that assumption and saying that science admits only a natural world. It is the second interpretation that privileges only science. Further, if science is experienced as that which engages in the unnatural tampering of life forms while denying the existence of supernatural and spiritual realms, then science is readily experienced as clashing against moral and ethical systems of belief.

In Canada and the U.S., curricular support materials encourage science teachers to acknowledge the belief systems of students while distinguishing such beliefs from scientific ways of knowing (e.g. Pan-Canadian Science Framework, 1997; National Science Teachers Association [NSTA], 2003). A recent NSTA text, *Evolution in Perspective, The Science Teacher's Compendium* (Bybee, 2004), "expounds on the premise that only those students whose schools teach them about nature of science will truly understand evolution" (Insights, 2003, p. 15). These curricular support documents present controversies—especially where science intersects with popular superstition—as healthy springboards for learning nature of science. Yet, when it comes to teaching evolutionary theory, for example, attention to an authentic view of nature of science remains inconsistent across classrooms in Canada and the United States (Aikenhead, 1992, p. 577; NSTA, 2003, p. 8). In a cross-Canada study of grade 11 and 12 students (Ryan & Aikenhead, 1992) at least half of the over 2000 students sampled were “predisposed to construct personal meaning of natural phenomena in a way that entertained the possibility of an intervention by a deity *and call that knowledge science* [italics added]” (p. 565). The difficulty here lies not in supernatural belief, but in a blurring of boundaries between spiritual ways of knowing and scientific ones. When these two worldviews collide, resolution is difficult. Either science is re-defined—adjusted to allow for non-natural explanations—as in the above example, or, in the examples that follow, science is used to discount the non-natural.

There exists a body of literature that expressly studies people’s belief in forces and phenomena that behave in non-natural ways; that is, in ways that run counter to the natural laws of science. In general, these studies both privilege and press western science as fundamental to the only viable worldview. They do so while taking a deficit view on anyone believing differently. Typically, such research seeks correlates between individual characteristics, often conducive to success in the sciences, and ascription to belief in non-natural forces and phenomenon—these falling under such categorical headings as superstition, belief in the paranormal, spirituality, religiosity, ascription to pseudo- or pretend-science, and faith in the supernatural. By promulgating a science image that privileges reason while devaluing other human ways of knowing (e.g., Saul’s intuition, imagination, ethics, common sense, and memory, 2001), this approach assumes an attitude that preaches to the converted while alienating others. Much that is written and expressed in this genre is summarized below.

Science literacy: From the view privileging science. A repeatedly expressed conundrum of those privileging science is superstition's continued existence in a world so coloured (and dominated) by science and technology. From a view that approaches scientism, such co-existence makes no logical sense and logical sense-making of empirical data is the only acceptable kind of sense-making. On these terms, it is irrational to uphold a scientific and naturalized worldview on one count and a superstitious and supernatural one on another. Indeed, ubiquitous throughout western culture is a way of thinking founded upon the logic of Aristotle and playing a profound role in shaping our prejudices (Davis, 1995; Nisbett, 2003). Taking Aristotle's Laws of Contradiction (*A* cannot be both *B* and *not-B*) and of the Excluded Middle (*A* must be either *B* or *not-B*) and combining these with a blanket endorsement of science's epistemological basis, then science's alternatives, *not-science*, must be wrong, and, worse yet, counter-scientific. At the extreme, one addresses a problem defined as poor knowledge and attitudes toward science by indoctrination about science, improved science literacy, and the active dismissal of other claims to knowledge.

Anthropologist, James Lett reports in the *Skeptical Inquirer* that, according to the 1991 Gallup and Newport polls, an overwhelming majority of Americans subscribe to some irrational belief (1992). He draws from Singer and Benassi in attributing this phenomenon to public uncertainty and insecurity about life, the unreliability of the media, and the inadequacy of the educational system. To this list, Lett adds an American enculturation persuading citizens that "nonrational thinking is perfectly appropriate in some cases" (p. 387). Note the alienating terminology that images a certain kind of science—one that privileges rational thought over alternative ways of thinking such as creative and intuitive thought. Yet, scientific consensus has it that creativity and intuition are vital to nature of science and scientific progress in general (McComas & Olson, 1998; Osborne, Collins, Ratcliffe, Millar & Duschl, 2003). What images, of science and of self, do words like "nonrational" engender in the minds of citizens? How well do they image science? Such questions are central to understanding the publics' understandings of science.

Much to the chagrin, and fear, of those embracing western logic on one side of a dichotomy with religion and superstitions on the other, mystical thinking is commonplace. One need look no further than religiosity's continued pervasiveness to be convinced. Unquestioning belief in supernatural forces and beings, existent beyond our senses, characterizes religious doctrine. Divine intervention suspends natural laws, as in the case of miracles, angels, and deities who answer our prayers. Superstition extends readily from religiosity—indeed, it is an integral part—and there is no doubt that our society is fundamentally religious. Repeatedly surveys and polls confirm that citizens honour faith supreme over other ways of knowing (Kaminer, 1999; Manohar, 1997; Ryan & Aikenhead, 1992; Sagan, 1997).

Relegating science and non-science to co-existing but non-intersecting parallel planes, which people are often inclined to do (Aikenhead, 2001; Costa, 1995; Zeidler et al., 2002), makes it possible to trust science while limiting the universal application of its underlying logic. Yet, from those adhering to an all-encompassing science worldview, this is problematic. There can be no other legitimate way of knowing. Superstition cannot be permitted entry because it unnecessarily admits a supernatural world that, in this view, threatens a return to the dark ages and medieval times of imagined realities and religious authority to keep evil at bay.

In an era where scientific research moves to increasingly obscure status and where scientific findings can press people beyond their tolerance and natural spiritual tendencies, one might expect a counter-science movement accompanied by a rise in mystic belief. The authors of the *2004 Science and Engineering Indicators* reiterate concerns elsewhere about the "public's susceptibility to pseudoscientific or unproven claims that could adversely affect their health, safety, and pocketbooks" (NSB, p. 7-21). Reporting relatively widespread belief in pseudoscience in Western nations, the authors afford various examples: In 2001, 56 percent of Americans polled said that astrology is "not at all scientific," while in Europe, where astrology is more prevalent, only 39 percent agreed (p. 7-22). In the U.S. skepticism about astrology was strongly related to education, but there was no such relationship among Europeans (NSB, 2004). Meanwhile, nine percent of Canadians reportedly trusted their daily horoscope and 31 percent said they had consulted a card reader, fortuneteller, astrologer or a medium, with 40 percent believing some people have the ability to predict the future (Globe and Mail, 2002).

Especially worrisome to scientists is the apparent overall rise in superstitious beliefs—evidence, for those ensconced in dichotomous thinking, that science is losing ground. For example, Gallup Polls in the United States, in 1990 and 2001 showed an average increase of just over seven percent on belief in 11 of 13 paranormal and psychic phenomena. In 2001, over 50 percent, of Americans surveyed, expressed belief in each of psychic healing and extra sensory perception (ESP). About 40 percent believed in each of haunted houses, demonic possession, and ghosts. And, between a quarter and just over a third believed in each of reincarnation, witches, astrology, communication with the dead, clairvoyance, alien visitations, and telepathy (NSB, 2004, p. 7-23).

Public surveys, such as have been discussed thus far, offer profiles of popular ascription to scientific, unscientific, and pseudoscientific authorities. Moreover, the reality is that beliefs in science, non-science, and "pretend" science can and do comfortably co-exist within cultures and within individuals. An entire genre of literature considers the factors mediating this co-existence of contradictory worldviews. Again, we should be mindful of the images these studies and views engender.

In his book, *The Demon Haunted World: Science as a Candle in The Dark* (1997), Carl Sagan stated that, "pseudoscience is embraced… in exact proportion as real science is misunderstood" (1997, p. 15). For that reason, he advocated improved science education as antidote to irrationality and superstition.

Researchers have sought correlates to explain persistent belief in the supernatural. The studies that follow relate this train of thought. Inherent in this approach is a perspective that at once privileges science and dismisses existence of the supernatural. Yet, science's success (though arguable[15]), based as it is upon a

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[15] Science would be deemed successful in terms of the human agency afforded through its understanding and application of natural laws. Thus far, we humans have been rather successful in using the power of science to flourish while controlling and re-configuring a world for human service. However, in the doing, science's success has enabled the maintenance of an anthropocentric charade that places humans outside the environment that sustains them. Inevitably the natural world that enfolds us, and that we are attempting to singularly unfold, presses back in ways unpleasant

worldview that counts all things supernatural as inadmissible to its inquiry, appears to legitimize, to science and most of western culture, such privilege. Indeed, science has and continues to demonstrate its consistent ability to explain away supernatural phenomena on strictly natural terms. It is fair however to note that the validity and relevance of such ability depends upon a particular scientific assumption: that a person's belief pattern should cohere to a singular all encompassing worldview—in other words, that contradiction is inadmissible (because it is illogical by Western scientific standards) within any individual perspective. In "Challenging images of knowing," Davis and Sumara (2005) assert, "Meaning and truth are not so much about the correspondences among referent and references, but about the coherences within systems of interpretation" (p. 307). Notably, there is no mention of coherence across different systems of interpretation—the desirability of which is the underlying premise of the studies to which this review now turns.

Craig (1997) studied the beliefs of 327 junior level education majors at Indiana University and found that over 30 percent of these pre-service teachers believed in psychic phenomena, extra-sensory perception [ESP], psychic prediction, creationism, the devil, and demons. Rejection of paranormal beliefs was strongest among: students with higher grade point averages, science and social studies majors, students with college educated mothers, students who considered religion to be unimportant, and students who exhibited a greater internal locus of control.

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for humans. Human cultures would do well to quickly disabuse themselves of such false beliefs, for the figurative dam of science's successes that separates humans from the natural world will break. There are already leaks. In this, science may well prove disastrously unsuccessful. It all depends how one defines success and how broadly one dares to look in the defining.

Gray examined the relationship of critical thinking with belief in the paranormal. In 1990 (Gray and Mill) and again in 1992, Gray asked graduate students to read one of three abstracts, all of which made unsubstantiated claims. In general, all groups failed to spontaneously recognize weaknesses in the abstracts. High willingness to endorse belief in the paranormal, especially belief in the reality of ESP (56% of respondents) was consistent with previous findings. However, Gray did not find any consistent link between critical ability scores and strength of belief in the paranormal.

Manohar (1997) compared the critical ability of pre-service teachers with levels of belief in the paranormal. Females were more likely to believe in extraordinary life forms. Critical ability showed an inverse correlation with degree of belief in the paranormal.

Yates and Chandler (2000) summarized earlier findings connecting paranormal New Age thinking and reasoning—naming projects, in 1989, by Blackmore and Troscianko as well as Wierzbicki and, in 1999, by Roberts and Seager that established an association between paranormal New Age type beliefs and reduced levels of performance on reasoning type tasks. They also reported work by Messer and Griggs, in 1989, that suggested a link between paranormal beliefs and lower university grades.

One can take several approaches to interpreting the above findings. To be blunt and at the risk of oversimplification, they seem to condescendingly set out to prove that superstitious people are “stupid”—then again, on whose terms and definitions? And there’s the rub. Science arose out of, and is largely based upon empiricism and rationality. For the authors of these studies, it appears that science represents the epitome of the human application of logical reasoning toward understanding and learning from and about the physical world. Similarly, academic success and high IQ scores reflect high verbal-linguistic and logical-reasoning ability. Thus, the derisive statement, Superstitious people are stupid, is a tautology on the order of: People who are less rational (as demonstrated in evaluations on the way they think) are also less rational (as demonstrated in their belief patterns).

If we then asked, Why are some people less rational than others, (and not set up rationality as the only and best way of knowing) we could invite less-privileging schemas. One might expect that evolutionary biology and complexity science could shed light in explaining the selected-for, and presumably adaptive (or at least neutral) emotional and spiritual characteristics of humans. On the other hand, one could frame them as flaws listed under such names as

> the fallacy of personal validation, subjective validation, confirmation bias, belief perseverance, the illusion of invulnerability, compliance, demand characteristics, false uniqueness effect, foot-in-the door phenomenon, illusory correlation, integrative agreements, self-reference effect, the principle of individuation, and many, many others. (Hyman, 2003, p. 22)

Do we accept anthropologist and geographer, James Lett’s conclusion that “scientists and skeptics should realize that it [the battle to diminish paranormal beliefs] will probably never be won” (p. 381) or do we reject the underlying contention that automatically pits these conflicting factions against each other?

This final collection of studies arises again out of certain researchers' biases that "if only people could think critically and rationally, then they would not be so superstitious." Suspecting that, in some studies, critical thinking skills were implicated in offsetting what was deemed erroneous belief in the supernatural, a number of researchers set about to investigate this relationship. I present this research to emphasize the continued prevalence of views that privilege science over other ways of knowing. Interestingly, the implied assumption that people who ascribe to non-naturalist beliefs lack critical thinking skills, is not borne out, despite expectations otherwise.

Mill (1990) found that, unless coupled with tutorials emphasizing real-world applications, training undergraduate students in critical thinking through introductory research method and statistics courses did not significantly enhance reasoning about everyday issues nor reduce their willingness to endorse belief in paranormal phenomena.

Royalty (1995) found a similar disparity between critical thinking ability and its application to belief systems. Among 109 Murray State University students, there was no correlation between scores on The Cornell Critical Thinking Test and the level of belief in paranormal phenomena. Critical thinking in statistical reasoning did not generalize to paranormal beliefs. Subjects seemed to retain two distinct, however conflicting epistemologies, depending upon context.

Walker, Hoekstra, and Vogl (2002) came to a similar conclusion, in their study entitled "Science Education Is No Guarantee Of Skepticism". Among 207 students across three small American universities "there was no relationship between the level of science knowledge and skepticism regarding paranormal claims" (p. 26). The investigators suggest that the inability to use scientific knowledge in evaluating irrational claims is in part due to the traditional method of scientific education: "Students are taught what to think but not how to think" (p. 26).

Bartz's (2002) suggestion is a likely exemplar of that traditional approach. He offers the use of a CRITIC acronym for teaching skepticism. In prescriptive fashion, this acronym dictates a stepwise application of critical thinking that avoids complex terminology as it walks students through its application. But the strategy contradicts itself, for the student is not given opportunity to turn critical thinking skills on the formulaic dictate thus prescribed. Indeed, it seems another case where "science students [are given to] accept theories on the authority of teacher and text, not because of evidence." (Kuhn, 1962, p. 80). Further, even if education were successful in training critical thinking, in calling for an examination of a study's methods of inquiry the method evaporates when that information is not forthcoming—a general condition of most media reports of science findings (Gregory & Miller, 1998).

In a California study, Priest (1995) taught 248 high school chemistry students to apply scientific thought to evaluate a particular instance of paranormal belief. Although instruction increased skepticism toward the particular belief studied, that skepticism did not generalize. There was no significant impact on the overall paranormal belief scale. Priest reported that only those students measuring high in logical reasoning ability shifted away from entrenched paranormal beliefs. He did not measure other modes of thinking and reasoning.

In contrast, Griffiths (1993) conducted a review of literature on critical thinking and advocated teaching science in a manner that reflected both knowledge generation and knowledge acquisition. She reasoned that since laypeople and scientists alike must depend upon other scientists, it was important for education to stress the reasons for trusting the products of science. This would be accomplished by emphasizing the ethics inherent in the methods of science—again an arguably privileging view that offers ethical science as a given.

The picturing emerging from the above studies is that critical thinking does not diminish belief in the supernatural—a belief that, according to these particular authors, runs counter to the fundamental scientific premise denying the existence of all things supernatural (Nisbett, 2005; Ryan & Aikenhead, 1992). Instead, and unsurprisingly, the research supports findings elsewhere that see science comfortably co-existing with other epistemologies within individual belief systems, including, I might add, those endorsed by many a scientist!

Legitimacy and the Social Construction of Science. In *The Social Construction Of Reality* (1967), Peter Berger and Thomas Luckmann develop a sociology of knowledge. They elucidate the pivotal role of legitimization and conceptual machineries in maintaining institutional lore, in this case, public knowledge about science. Legitimation is needed when the self-evident nature of an institutional order "can no longer be maintained by means of the individual's own recollection and habitualization" (p. 94). A process of explanation and justification ensures that each subsequent generation apprehends as legitimate an institution's authority on the nature of reality. Thus an institution, apprehended as legitimate, is perceived as trusted purveyor of knowledge. Berger and Luckmann's four levels of legitimation describe four levels of apprehension, each contributing to a pragmatic trust in the institutional order.

At the pre-theoretical level, incipient legitimation is "present as soon as a system of linguistic objectifications of human experience is transmitted…. The fundamental legitimating 'explanations' are…built into the vocabulary. For example, …a kinship vocabulary *ipso facto* legitimates the existence of a kinship structure" (p. 94). In the case of science, its vocabulary, as encountered in everyday life (for example: experiment, invention, vacuum, energy, gravity, chemical[16]) *ipso facto* legitimates the existence of something called science. Berger and Luckmann describe a second theoretical level characterized by simplistic explanatory schemes such as sayings—"An apple a day keeps the doctor away" or folk tales. For example, the child may encounter stories of science heroes who, under adverse conditions, even as recluses or under persecution, work diligently and tirelessly in the scientific method to uncover revolutionary truths and devise ingenious technological tools.

Even so, the detailed workings of science have long moved beyond what can be transmitted through stories and everyday language. Besides the wonders of modern life, science has issued in some unwelcome consequences. For example, nuclear weapons and medical blunders wherein science's reassurances have turned up disastrously wrong are two motivations for diminished trust. In keeping with Berger and Luckmann, explicit legitimation becomes necessary when institutional

[16] Note that such words, although recognized as scientific, engender difficulties in communication because their everyday interpretations have evolved considerably from their scientific origins.

knowledge eludes apprehension in everyday life. At this third level, "because of their complexity and differentiation, they [legitimations] are frequently entrusted to specialized personnel who transmit them through formalized initiation procedures" (p. 95). Here then, science educators, science journalists, media personalities, and museum personnel serve as science transmitters. Surprisingly, Berger and Luckmann observe that these transmitters "do not transmit this particular stock of knowledge because they know it, but they know it (that is, are defined as knowers) *because* they are" transmitters (pp. 70-71). While these transmitters have the role of presenting science as a legitimate institution, being transmitters and not scientists *per se*, they will, themselves, need convincing reasons to trust in the legitimacy of science as they understand it to be. To be sure, at the second level of legitimation, the myth of uncontroversial science is often the reason upheld for trusting science in the first place. As we have already seen, where this is promoted, subsequent encounters with the uncertain and multifarious elements of science will diminish trust in science because it fails to live up to its reputation.

Finally, at the fourth level of legitimation, the symbolic universe transcends everyday life and extends its explanatory function beyond the pragmatic into such alternate realities as dreams, death, play, religion, mystic experiences, and cosmology (Berger & Luckman, 1967). Science's explanations—summoning entities and conceptualization not even remotely reminiscent of everyday life, bereft of sacred legitimation, without promise of retribution or reward for wrongs endured, without assuagement against any of the human terrors, and seemingly void of moralizing talk—pale in the face of alternatives (Crow, 2001; Holton, 1992; Kurtz, 2003;

Stillingfleet, 1666 in Gould, 2003). It is perhaps here that science deals itself its most debilitating blow as a legitimate institution[17].

Can citizens retain trust in science but at the same time dismiss its final level of legitimation in favour of more comforting theological or mythological explanations? If citizens experience science as situational, atomistic, and generally not applicable to everyday life, then any conflict with theology and mythology is neatly averted. Thus, in the context of institutions offering competing symbolic universes, this particular strawman image of science is least problematic to everyday living and may well be an important reason for its stubborn presence.

Indeed, despite historic predictions to the contrary, at the end of the 20th century, "it is not science but religion which…is perhaps the strongest force in private and national life" (Gerald Holton, 1992, p. 106). Still, while 60 percent of American adults ascribe to belief in a literal biblical Hell (Holton, 1992), concurrent high levels of public trust and confidence in the scientific community continue to be reported (NSB, 2004). The large majority of Americans view conflicting belief systems, be they of science and faith, as largely unproblematic (Holton, 1992)—a phenomena

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[17] In fact, in a pattern-seeking species that reflects upon its place and meaning in the world, one can construe a survival advantage for those who strive for a "good" life, as socially defined, in this world, in order to achieve the surreal rewards of an afterlife. Else, under insufferable conditions, why continue striving to exist? That the right temporal lobe houses built-in tendencies to "short-circuit" sensory perceptions and configure alternate spiritual realities (Buckman, 2000)—at once frightening, other times enticing—is no physiological nor evolutionary coincidence. One can imagine that, in the face of adversity some 50,000 years ago, any groups of homo sapiens who lacked mystical belief, however ensconced in rudimentary religions, would have shared a survival disadvantage. All other inherited tendencies being equal—including a sense of justice and altruism characteristic of social animals (Howes, 2004)—having less reason than their spiritual counterparts to struggle against all odds for survival, they, quite simply, would have been more amenable to giving up.

attributed by those endorsing a deficit public model to the irrational nature of belief and poor public understanding of science. Recent social epistemic work, highlighting the interplay of epistemic and non-epistemic forces in practical everyday decisions, affirms the nature of belief as beyond evidence and rationality (Hare, 2003). Meanwhile, taking a deficit model of public science literacy, with thresholds of appropriate understanding set by the National Science Board, it is not surprising to read, "approximately 70 percent of Americans do not understand the scientific process, technological literacy is weak, and belief in pseudoscience is relatively widespread and may be growing" (NSB, 2004, pp. 7-34).

To summarize, regardless of the *actual* legitimacy of scientific knowledge, its trustworthiness—particularly in matters relating to everyday life—depends on elements of socially constructed and agreed upon *perceived* legitimacy. That being the case, if we are to come to grips with the publics' understandings of science, especially in the face of conflicting authoritative renditions on reality, we would do well to: (a) examine images of science's nature through the eyes of the public beholder, (b) consider where these images come from and how valid they may be, and (c) investigate ways of improving two-way communication between science and the public, that, when warranted, trust relationships running both ways may be fostered. It is to the first issue that I address my attention in the proposed study.

Matters of Definition

On the Nature of Conception, Perception, and Awareness

It might seem odd that I have left, till this late point, the task of developing the notions of conception, perception, and awareness—in short one's collected experience. What follows is an exploration of social representation theory [SRT]—which describes how names act to objectify, codify, and thus impart a certain sense to situated experience. The characteristics and commonalities of notions of perception, experience, and awareness are developed in chapter 3's methodological discussions of phenomenography. But first, an exploration of "image study" is in order.

In previous pages, I spoke with an assumption of certain consensual or common sense understanding of images and built upon that familiarity by drawing examples of images of science in written media, television, public education, and science exhibits. I also advanced the notion of image study (in the metaphorical sense of a social representation) as potentially a more neutral method of study of social phenomena—a contention supported by Andrea Hemetsberger's analyses of the methodological implications of using SRT in research on collective action on the Internet (2002). I further presented image study as particularly appropriate to a problem re-conceived, no longer as scientific illiteracy, but rather as inadequate communication of and about science between specialists and lay people in embedded contexts where science matters. I deem communication unsatisfactory when it promotes the further separation rather than the appreciation and bridging of separate worlds of thought. In the case of science communication, these difficulties impede the mindful, collaborative stewardship of science in the 21st century.

I now turn to SRT for a more elaborated description of image—one that positions image amongst the related notions of attitude, concept, and social representation. These differentiations figure importantly in conceptually demarcating the object of this study.

Social Representations

In conceiving and explaining his notion of social representation, Serge Moscovici (1988) explicitly averted an oversimplified definition and instead embraced the ambiguity inherent in the complexity of that which he sought to describe. I take the same approach to image and experience. Moscovici gives that social representations are the products and processes of human sense-making of the world, or of world-making in human sense. To know something "out there", we need to move beyond sensing it, we need to bring it in, to cognate it "in here." We do this by reifying it, that is, by both naming it and categorizing it in terms of those things we already know. In this anchoring process, the strange and abstract world becomes familiar, concrete, and manageable. The name affords a communicable label to train awareness and objectify the intangible into an analogous, tangible concept or image that itself comes to embody the directed experience of the thing named.

For example, when an individual encounters an unfamiliar entity, say an as yet unnamed physical illness, the strangeness of it presses for identity that the individual and others might acknowledge it, know of what class it is, and know what to expect from it. In naming it, and connecting it to—and contrasting it against—the familiar, this abstract entity becomes anchored in the existing scheme of things. It becomes real and objectified, moving from the consensual universe to a reified one. Thus, for example, the symptoms of listlessness, fatigue, aching joints, and muddled thought processes, when named Chronic Fatigue Syndrome, move toward a distinct and socially accepted reality. As concept and image acquire coherence and clarity in a reified universe, the subjective is affirmed as objective so that, in lay terms, the person "knows [and can communicate] what they are dealing with."

Consider, also, an example from science. The mysterious work of the scientist is made understandable metaphorically through prose, sensorial imagery, or story. Thus, we see, hear, and read about varied portrayals of the scientist as, for example, recluse, mad man, naturalist, healer, et cetera, all of which constitute instances of science-making in public or the public-making of science. Depending upon the metaphor that is referenced, or attended to, various understandings of science ensue and enfold into the subsequent mix of future images and understandings. This process of *re*presentation is an ongoing and reflexive one, such that, the "contents that are shared by a whole society lead each mind to draw its categories from them and these categories impose themselves on everyone" (p. 231). In this, the theory resonates with complexity science where the whole is seen both to enfold and unfold the parts (Davis, 1995). Notably, representations are co-created by people—lay individuals side-by-side with experts—and the resultant network becomes an enacted evolving merger of conceptualizations, themselves constituting "reference point[s] for interpreting [future and re-interpreting past] events and relationships" (Moscovici, 1988, p. 227). Social representations in the form of images, symbols, and labels, and the texts and scripts that evoke these, are the visible, and empirically measurable artifacts of Berger and Luckmann's socially constructed reality. They "shape what is loosely termed a social consciousness" (p. 228).

In sum, social representations constitute the "core of collective memory" and the "prerequisite for action in general" (p. 214). They "concern the contents of everyday thinking and the stock of ideas that gives coherence to our religious beliefs, political ideas and the connections we create as spontaneously as we breathe” (p. 214). They exist in both the minds of individuals and the visible public spaces between. They operate at the interface of the psychic reality of imaginations and feelings and the external reality of a co-created collectivity. Representations are networks of “interacting concepts and images whose contents evolve continuously over time and space.” Importantly, the nature of that evolution depends upon “the complexity and speed of communication…[and] the available communication media” (p. 220). Thus, if we are interested in the various publics’ understanding of science, we can look to public representations and communications of science.

Image in Relation to Social Representation and Concept

With the above explication as backdrop, I would attend to several distinctions and clarifications for the purposes of this investigation. Whereas social representations invoke elements—both images [literal and figurative] and concepts [intellectual]—these components, according to Moscovici, are different and develop independently (1988, p. 236). The literal and figurative image can seem both “rawer” and more refined than the intellectual concept. An image is apprehended through sensorial and affective experience; that is, at a “rawer” or more acute, primal level. By taking direct routes to percept and instinct, images can circumvent conscious thought. The primitive brain includes such regions as the amygdala, the limbic system, and the spiritual right temporal lobe—in short those areas that are less cerebral. In imagery, this would be thinking with the heart and spirit. Yet, images, as cultural artifacts, are also more refined because they are humanly created products emerging from a human collective. They can be thought of as the reified and now "visible" (that is, imaginable and fathomable) crystallized precipitates of collected and agreed upon experience, which subsequently, and in cyclical fashion, become subject for individual apprehension, again at a primal level.

Whether conceived in the act of seeing and imagining, or generated and regenerated as cultural artifacts, images are humanly constructed representations of our reality. When we see parts of a written symbol, icon, or drawing we mentally fill in the missing lines while accentuating boundaries and differences (Davis, 2004). A phenomenographic understanding of awareness extends this observation of human habit in seeing to all manner of experience; that is, when encountering parts of an entity, whether through sight, sound, smell, touch, or imagination we are prone to mentally fill in the missing components so as to both distinguish the entity as against its background and to cause the thing experienced to hold together in some form. Both the medium of representation and the requirement of coherency in a figurative image will necessitate some pruning or compromise of incongruent parts, together with interpolation to fill in missing elements. Humans tend to complete images and to stylize them into meaningful, useful, stereotypic caricatures. Our ability to discern is "biologically rooted and culturally elaborated" (p. 6, Davis, 2004). Noticing similarity and difference—even exaggerating these—is essential to survival.

We discern best through our visual apparatus. More than any other sense organ, our eyes can simultaneously process multiple bits of information. Yet, owing to the time-independent nature of sight and the time-dependent nature of thought, our brains must choose which information to attend to at any given time. The images apprehended in our mind's eye—that which we *see*—are a consequence of selective attention. In public forums images are both co-creations of collective minds and important agents that subsequently speak back. Accordingly, literal images of a phenomenon speak directly to the public experience of that phenomenon—in this case, science.

Moscovici prioritizes literal images as prime vehicles for anchoring an abstract concept to common-sense familiar understandings of experience. They constitute emblems of collectively enacted reality. As he puts it, "In recombining cognitive elements [,] an image is particularly apt to 'make one see'…. [Through images,] ideas… are transformed into perceived objects" (p. 237). Images are "more directly social" and are "stabler" than concepts. They "have the advantage of linking us to the past and of anticipating the shape of things to come" (p. 237).

Yet literal images are never far removed from figurative image and concept. Humans, having extended perceptual tendencies into conceptual habit, "are constantly making conceptual distinctions—and often amplifying them. The habit is vital for our processes of self-definition and collective identification—to our having a reality" (p. 6, Davis, 2004). Figurative images, existing as coherent wholes in one context, often transmute to something different when context changes—so too for conceptions of a phenomenon. Further, we use the flexible and powerful technology of language to enhance our ability to discern and make meaning. "Through naming, contrasting, likening, and other acts of association and dissociation" we "weave possible worlds" (p. 7, Davis. 2004) and configure, reconfigure, and negotiate a shared reality. For these reasons, discourse analysis complements figurative and literal image study as a prime source of data for informing the experience and awareness of science. In short, if my goal is to explicate the nature of science as socially constructed, then I should find useful data among studies of the social representations of science.

Positioning Image[18] as Distinct but Related to Attitude, Perception, Trust, and Belief

Studies in science literacy and the public understanding of science often focus on public attitudes and public perceptions, at times calling these images. Is there a distinction important to this study? Further, given that I have emphasized trust and belief in the above pages, how do these relate to images?

Bergman distinguishes between attitude and social representations. Whereas, "attitudes are positions [either generalized or context-dependent] toward something abstract or concrete," social representations are "systems that transform the unknowable into something knowable" (1988, p. 82). Social representations, concepts, and images "give rise to values and attitudes, but are concurrently formed by these" (p. 82). Attitude is the feeling taken to the experience of an already imaged concept. Conversely, the experience of an image may be said to evoke a certain attitude, but it is not itself the attitude. Whereas an image points to the experience of a visible artifact—the concept residing and represented in it—attitude rests in a value judgement drawn by the observer. For example, if an image portrayed science as impersonal and objective, the portrayal, objectified as it is, would not in itself constitute attitude unless a subjective value were brought into the mix. An attitude component would entail how an individual felt about, in this example, science's

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[18] For reasons explicated above, and to avoid future confusion, note that, from this point forward, unless otherwise indicated, this paper takes the term image to include both its figurative and literal interpretations.

seeming neutrality. Note that individual attitudes might differ—neutrality might comfort one person, but trouble the next.

Like attitude, perception is in the eye of the beholder. How one perceives a particular image of science when juxtaposed against one's needs, desires, and values will largely affect attitude. Though we can co-conceive images, we do not co-perceive. Indeed, in this line, Verheggen and Baerveldt (2000) takes issue with Moscovici's notion of a shared reality and would substitute an enacted one. I agree. Both public images (iconic and stereotypic) and private perceptions (likened to mental images) are derivative, instantaneous points, tangential in the moment, on a curve whose shape and contour is forged out of the interplay of individual and collective being and sense-making. Attitude mediates between perception and conception.

> "Since we principally have no access to the experiences of others, we cannot share similar—let alone the same—experiences, representations, scripts, models, and the like. What people 'have in common' is not a set of ready made ideas but a history of interlocked conduct; the experiencing agents are parties to consensual domains" (Verheggen & Baerveldt, 2000, Final remarks section).

While interesting, examinations of attitudes alone fail to speak to science's public image or its perceived nature. Remembering that the present study seeks to generate a typography of the varied *experiences* of the nature of science, any study of attitude must, at a minimum, also address the thing to which attitude concerns; that is the actual experience or image of science. Studies of attitude that overlook this vital piece typically do so as a consequence of a monolithic understanding of public awareness of science. Hence, in failing to either examine public artifacts of science or investigate personal narratives about science, such studies of attitude could not inform the present project.

On the matters of trust and belief, Moscovici describes confidence in a social representation as trust in the shared [I prefer enacted] information and judgements embodied by that representation; that is, trust that everyone agrees with the image's portrayal of reality. In the case of science, we encounter multiple orders of trust, each co-dependent on the other. We can speak of trust in the scientific community, in scientists, and in the various layers of information that science offers. Trust in the epistemic authority of science will influence trust in the images and conceptions that science offers, and vice versa. Trust inextricably intertwines with image and conception. At the same time, representations of and from science, filtered down into public places, arrive as transformed co-created entities with audiences usually unaware of any transformation. The extent to which an individual "believes in science" is the extent to which (s)he has confidence that the social representation understood as science—or a subcomponent of science—is a reliable and valid creator of social representations of the natural world. Put differently, one might find reasons to believe in science and therefore trust its dictates, or one might find reasons to believe its dictates and therefore trust science.

Consider the following example. Say I believe in science because: My family holds it in high regard; my aunt is a scientist and seems to know about everything; my doctor is known for his concern and integrity; and I particularly liked my science teachers in school—they made science fun and had a fascinating, albeit confusing, way of explaining how the world worked. I was regularly "wowed" by science's magic but whenever I completed school experiments, I was bored by science's overly cautious and tedious ways. We were made to wear goggles during labs for no apparent reason. We might say that I subscribed to a particular social representation of science as ingenious but unnecessarily careful. Then when science, in turn, speaks of a hole in the ozone layer, and the desirability of ozone, I trust and have confidence in the subsequent co-created reality of ozone as protector—an image that I think comes direct and in tact from science. In that image, I may well envisage a literal and clearly demarcated hole in a special type of air cloaking the earth and I might further purchase an ionizer to make ozone, which in my thinking must be a good thing to have. Moreover, when I hear scientists talk about the problems of climate change, I think that in their caution (remembering how careful we had to be in science class), they overly exaggerate. My confidence in the image of science as ingenious includes the expectation that science will find a solution.

Once people attach a sufficiently coherent schema to a particular context, that is, once comforting order is established, people will tend it and, preferring the ordered familiar, will move to re-configure that which seems strange into pre-established contexts. An accepted social representation is valuable and clung to because it "means, for the subjects, a way of understanding and 'dominating' the knowledge that 'affect' [sic] them" (Rangel, 1997, p. 54). Hence, individuals strive to preserve their confidence in a particular social representation of science, such as in the above example, by apprehending science with pre-conceived expectations and selectively attending to only those aspects that confirm and reaffirm the already taken-to-be-true notions. In addition, individuals act as social agents to promulgate the particular images that they hold, subtly negotiating and re-negotiating these with others who hold similar images. In this fashion, the various images of science in public places reflect private images and, though not static, have sufficient inertia to be considered stable. Accordingly they are prime targets of study.

Nature Of Science

> Lack of understanding [of science] is potentially harmful, particularly in societies where citizens have a voice in science funding decisions, evaluating policy matters and weighing scientific evidence provided in legal proceedings. At the foundation of many illogical decisions and unreasonable positions are *misunderstandings of the character of science* [italics added]. (McComas et al., 1998, p. 3)

If looked at from a different angle, statements, such as the one above, hint of an alternative way of framing a problem of science in society. It might be put that s*cience's current reputation does not match its professed self-concept, or at least the desired image expressed by spokespeople from the scientific community*. Further, in ways unacceptable to science (because in the scientific view the situation compromises wise decision-making), this reputation limits science's credibility and influence while further restricting any practical agency and autonomy scientists have.

If I have a reputation problem, that is, if I think that my public image or images misrepresent me or that they present certain characteristics about me that I wish kept secret or set in better light, what questions could I ask? I might look to rapprochement for a solution. Perhaps I have this reputation because I have not let people know me—I have been too distant and in my absence, or limited presence, people's imaginations have gotten the better of them and they have inferred interesting falsehoods. On the other hand, it could be that this is the reputation I duly deserve. Perhaps in public images of myself there are unpleasant truths for the learning. In either case, my collected public image(s), my reputation, does not belong to me. Together the co-constructed images portray a virtual reality of me, which in the naming becomes the concept of me to other people. And, owing to its co-constructed nature, we should find, entailed within these images, clues to the perceptions and ways of thinking of the constructors. Each image has much to tell of both public and self. And the collected pattern of images is a mirror embodying and reflecting newly evolved and generated realities that are continually co-created at second, third, and subsequent levels of enactment.

If we wish to consider public images of science, we would do well to first articulate what the scientific literature claims its nature to be. This is a less than simple task, not only because of the complexity of science, but because of differences of opinion within and across science's disciplines and across those disciplines whose business it is to study science, namely the history, philosophy, and sociology of science.

Science's Self-Perception

So, how *does* science describe itself? Or rather, how do scientists describe themselves and the nature of their work in general? It depends which scientist or person involved in the sciences you ask. The considerable differences in science's nature across sub-disciplines, the particular focus one takes, and the degree of specificity considered make a singular and fair response a next to, if not, impossible task. In fact, do scientists or representative scientists describe science more or less, better or worse, than those disciplines that have taken its nature as subject?

It would seem that being a scientist does not necessarily make for an authoritative view on NOS. Indeed, conceptions of NOS and tools to measure understanding of that nature arise, not out of science, but out of science studies. That is, the agreed upon authorities on NOS are historians, philosophers, and sociologists of science—and in certain respects they do not all agree. Still, agreement is reportedly sufficient enough to allow for the creation of measurement tools on NOS. These then have been applied to scientists.

In a literature review of studies on the relationship between NOS knowledge and explicit and direct experiences of science—these including: number and type of science courses taken, success in such courses, fieldwork in science, and employment as a practicing scientist—McComas et al. report no significant correlation. That is, direct experience in science is no guarantee for understanding its nature. In general, "science teachers and scientists expressed traditional views of nature of science…. [a]s objective, empirical, and involved with issues of the control of nature" (McComas et al., p.26). The researchers explained that these positivistic ideas likely reflect both the participants "deep initiation into the norms of the scientific community" and their work within Kuhn's (1970) "normal science" paradigm (Pomeroy cited in McComas et al., p. 26).

Coupled with multifarious public images about science, it could be said that science has at least three *classes* of natures, a broad scholarly one, as described by those looking at the enterprise entirely and from without, a situational one as variably experienced by the practicing scientist, and a socially vetted one as constructed out of the multiple-personalities of science imaged in public spaces[19]. I am, at this point, less prepared to dismiss the scientist's perspective, that is to say that one view is more correctly descriptive than the other. However, as far as I know, the current state of the literature does not offer a description of scientists derived out of studies of their nature, nor does it afford summative descriptions of scientists' work as scientists see it—a state of affairs that I find decidedly odd. Nonetheless, I cannot fairly answer the question, How does science see itself? Instead, I turn to how those that study science describe it to be.

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[19] These three classes of the natures of science can be thought of as the analogous constructions of science emerging from John B. Thompson's theory of culture. The culture involves negotiation between three "moments of meaning", namely, the producers of cultural products (in this case, scientists), the receivers or audiences (publics), and the analysts (here, the scholars of NOS) (Locke, 1991). Until recently, historians of (western) science, *qua* analysts, typically colluded with scientists and "foreclosed any study of the interactions between élite science and popular science. Science as product was boxed away from society, its production epistemologically privileged, its audience conceived as entirely yielding to new forms of natural knowledge" (p. 240). This historically typical analytical approach, advocated against by Thompson (1991) and Cooter and Pumfrey (1994), takes a diffusionist model of the popularizaton of science, that is, one that sees popularizaton as a necessary vulgarization of science that "dumbs it down" for public consumption. It is an insufficient model because: (a) it denies that "popular culture can generate its own natural knowledge which differs from and may even oppose élite science. [And, in this, the authors emphasize, they] are emphatically *not* thinking…of popular lore and magic" (Cooter & Pumfrey, p. 249) and (b) it assumes that popular science entails a simple acceptance or rejection of élite science, when "a more sophisticated reading would have the 'lower orders' treating the products of elite culture as resources which are appropriated and reconstituted" (p. 249).

Consensus or Compromise: A Nature of Science for Schools

The term NOS refers to "understanding about the social practices and organization of science and how scientists collect interpret, and use data to guide further research" (Zeidler et al., 2002, p. 345). Lederman (1992, restated in 2003b) offers a description of the NOS as typically referring to "the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development" (p. 87). In philosophical parlance, this notion of a NOS presupposes an essentialist view that: (a) "There is a nature of science to be discovered and taught"; (b) "a list of tenets can describe the nature of science"; and (c) "for a discipline to count as a science, each of the tenets must be true of that discipline" (Eflin, Glennan, & Reisch, 1999, p. 108). Yet, most philosophers of science and science educators do not ascribe to this essentialist outlook. Instead, they take a *family resemblance* perspective to the notion of science, such that "'science'… denotes…a series of paradigmatic examples and…a rider such as 'and other closely similar activities'" (p. 108). Are we then to dismiss the notion of NOS altogether because at the outset it misrepresents science?

One should understand by now that, to the degree that social representations are generated and live in public spaces, they exist as loose, apprehendable, approximations of the real world. Elfin et al. admit a certain pedagogical appropriateness of essentialism about the standard science education label of NOS. Apart from their legitimacy in NOS, one can expect two sorting criteria for those elements prescribed for schools: (a) The features of science chosen for emphasis should be within students' intellectual and emotional grasp and (b) they should attempt to redress current misconceptions and gaps about science's nature. From the outset then, when we are talking about the NOS (or a particular NOS if we want to be closer to the mark), we are already dealing with a social representation of science that has been reconfigured, in a word, compromised, for the purpose of public consumption in an educational context, largely for the perceived (by their creators) mutual benefit of science and society. Within that construct two recent studies offer consensual departure points for NOS, as best approached in schools.

The first of these studies was conducted by McComas & Olson (1998) who reviewed and qualitatively analyzed eight leading science education standard documents, four from the United States (written in 1990, 1990, 1993, & 1996), and one each from Canada (1996), England/Wales (1995), Australia (1994), and New Zealand (1993). They reported a "high degree of agreement about the elements of the nature of science that should be communicated to students" (p. 41). Further, the researchers found that the term, NOS, as used in the curricular documents, drew descriptors of science from philosophy, history, sociology, and psychology.

Assuming that the concept of NOS is culturally influenced (as curricular documents reiterate), and in the interest of fair representation of the five societies, I include only the findings from the more recent and comprehensive National Science Standards document (1996) as representative of the position in the United States. I grouped the list of descriptors, found to occur in some form in the documents, categorically and in decreasing frequency in order to arrive at the following summarizing characteristics (from McComas & Olson, 1998, Table II matrix, pp. 44-48).

On the nature of scientific inquiry, students should know that science attempts to explain phenomena by observing and gathering experimental, empirical evidence about the world. Its nature is skeptical and its, always tentative, conclusions are based on careful analysis and logical argument. There are many ways to do scientific investigations, but to learn how science operates students must know the vocabulary of science and the role of theory, observation, and hypothesis.

Scientists themselves are creative individuals who must be open to new ideas. Scientists make ethical decisions and must be intellectually honest. Much care is taken to ensure the integrity of scientific work. Scientists require accurate record keeping, replicability of work, and truthful reporting. New knowledge must be reported clearly and openly.

Finally, the curricular documents describe the nature of science in society: Science plays an important role in technology and is, in turn, impacted by technology. Despite science's global implications and the care taken in science, it remains a human endeavour and part of a social tradition to which all cultures contribute. This means that science ideas are affected by their social and historical milieu and, over the years, these have been at the center of many controversies. Change occurs in science, both gradually and through revolutions.

The above-named characteristics of science occurred in at least three of the five national curricular documents. However, both the most and least frequently named descriptors give us a picture of the characteristics of science that curricularists are currently more and less inclined to emphasize. The following elements occurred in only one or two of the five national science standards documents.

Fewer curricular documents chose to include that: Science aims to be precise. It is objective and consistent. Scientists work collaboratively and require peer review. Science knowledge, though stable, will never be finished. The past illuminates current scientific practice, so that science builds on what has gone on before. There are inherent limitations to science. While, new scientific ideas have frequently been rejected, change occurs out of the information of better theories—those theories guiding the way that science observes.

What can be drawn from the above descriptions? Curricular documents want students to learn something of the empirical processes involved in science, notably the empirical nature of observations, the testability of science findings, and the rational skepticism inherent in its inquiry methods. Students should know of the checks and balances built into science processes to maximize the integrity of science knowledge. These qualities speak to science's reliable objectivity and consistency. Likewise, the scientist is portrayed as a careful, trustworthy collaborator with a creative, open mind. By this account, (s)he is likable and approachable—neither mad recluse nor academic "geek".

At the same time students encounter statements that appear to contradict science's trustworthiness. Students should, after all, understand that despite scientists' valiant efforts and science's careful structure, the knowledge obtained can never be certain. There are human frailties and cultural biases in the mix. The bottom line then, is that science's epistemology is no more or less trustworthy than other well-meaning and noble enterprises. NOS, presented thus, is still drawn in prescriptive, albeit offsetting, black and white fashion, with much of the grey middle ground avoided and the colour of the socially relevant missing. Are we doing a service or a disservice in such bimodal representations of science? In oversimplification, do we not hover somewhere between scientism and naïve relativism in presenting science?

Conspicuously absent or minimally emphasized in the above accounts are five hotspots for misinterpretation about science: (a) the non-essentialist character of science evident in diverse methods and natures across its sub-disciplines, (b) the degrees of tentativeness in science especially between established and frontier science, (c) the roles and natures of models, theories, and laws in describing the physical world, (d) the socioscientific nature of inquiry in terms of choosing and framing both questions and subsequent investigative designs, and (e) the distinctions between cause, correlation, and qualitative descriptions in answers given. Having taught elementary and secondary science for more than a decade, I am convinced that, though difficult, these latter understandings are well within the grasp of students moving through the K-12 curriculum. Indeed, this is the stuff that makes science interesting and relevant.

A second group of researchers (Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003) undertook a different tact for delineating NOS elements suited to science education. Using a "three stage Delphi questionnaire with 23 participants drawn from the communities of leading and acknowledged international experts of science educators; scientists; historians, philosophers, and sociologists of science; …and expert science teachers" (p. 692) the authors derived nine consensual themes to represent the bare minimum that any simplified account of science should address. The themes parallel those emerging out of McComas and Olson's findings (see

Osborne et al., 2003, Table 4, p. 713), thus reinforcing the notion that consensus about the NOS for educative purposes, is possible. However, the details emerging from the Delphi study suggest greater attention to the aforementioned messy grey areas that I have listed as fertile grounds for misinterpretation of science in public. The study group felt that any NOS component to curriculum should address:

1. “Scientific method and critical testing” through active student engagement in inquiry design and process (p. 706);

2. “Creativity” in action (where students design models and devise plausible and testable explanations) to counter caricatures of scientists and encourage students into science (p. 706);

3. The “historical development of scientific knowledge” to emphasize the human and social elements of science (pp. 706-707);

4. “Science and questioning” to prioritize the ongoing and cyclical nature of inquiry thinking (p. 707);

5. “Diversity of scientific thinking” to “help nip scientism in the bud” and to provide students with a “toolkit of scientific methods to test their ideas” (p. 707);

6. “Analysis and interpretation of data” so that students might critically assess knowledge claims arising out of new data (p. 708);

7. “Science and certainty” wherein students learned of the provisional nature of knowledge and the differences between controversial and non-controversial science (p. 708);

8. “Hypothesis and prediction” as a creative endeavour for theory testing and as “antidote to ‘just fact collecting’” (p. 709); and

9. “Cooperation and collaboration in the development of scientific knowledge” to counter the image of science as the “retreat of the lone genius” and to emphasize the social processes of science “fundamental to understanding both the contingency and the reliability of knowledge” (p. 709).

Inherent in the above list of science characteristics are attempts to remediate images about science and to squarely face the non-essentialist nature of science. I took the data from Osborne et al. and rank-ordered prioritizations for each class of experts, yielding interesting patterns. Scientists emphasized themes about method, positive images of scientists, and the reliability of science knowledge. Teachers placed creativity first and prioritized the social aspects of understanding, interpreting, and doing science while de-emphasizing difficult concepts associated with statistics and empirical design. The philosophy and sociology group ranked the more theoretical elements above the “how-to” of experimentation, while science educators and public understanding of science experts both emphasized the process of science in its social context with higher priority on critical ability to assess science knowledge. Although, consensual characteristics were derived, there remained considerable variation in their prioritization.

If the above characteristics of science tell us anything, they speak to its complexity and multiple natures as seen even in subtle differences between comparable experts about what is most important and attainable for people to know. This state of affairs makes “good” representation—in the absence of collaborative sites of communication between science and public—a seemingly elusive and utopian goal. Not surprisingly, controversy about science’s definition and nature is pervasive—captured expressively in the past decade's descriptive term: "science wars."

Controversy from Ivory Towers

> In most societies, the normative view of what is significant and salient within a given domain is defined by the academic community. However, contemporary academic scholarship would suggest that the nature of science is a contested domain (Alters, 1997; Labinger & Collins, 2001; Laudan, 1990; Taylor, 1996). (Osborne et al., 2003, p. 693).

To what degree is it wise, or even possible, in a pluralistic democratic society, to spare people from complex and conflicting renditions of science's nature? Mike Fortun and Herbert Bernstein (1998) argue, "people need an understanding of the sciences that is more complex than conventional [stylized] accounts" proffered by those on opposite sides of debates about its nature (p. *xi*). Are they right? And if so, how should we proceed, especially in the face of various publics often averse to tackling the very complexity that supposedly warrants attention?

Several authors have presented dichotomous representations of science—caricatures that have seeped from the arenas of scholarly conflict, often through popular literature[20], into public places to subsequently take on lives of their own. Let loose, these accounts individually skew, and collectively obscure and confound, science's nature and the perceived legitimacy of its material and ideological offerings.

[20] Examples of popular image-making texts include John Ralston Saul's *Voltaire's Bastards: The Dictatorship of Reason in the West* (1992), Carl Sagan's *The Demon-Haunted World: Science as a Candle in the Dark* (1996), Collins and Pinch's *The Golem: What You Should Know about Science* (1993/1998), and Gross, Levitt, and Lewis's *The Flight from Science and Reason* (1996).

Such upheaval may or may not play out to ill effect, but the literature is not lacking in predictive forecasts as varied as the predictors—each utterance voiced with assured conviction and followed with prescriptive pre-emptive action. Fortun and Bernstein note, while "few things are more dangerous than unmuddled absolute faith in any answer or method, scientific or political" (Fortun & Bernstein, 1998, p. *xii*), the temporal distance of historic science and the conceptual distance of current science render these easy prey to "unmuddled" absolutes as encountered by the public.

At the center of current controversy is the degree to which science knowledge has been socially constructed, (and in "right brain", linear thinking, powerful, male-dominated fashion) and therefore undeserving of any privileged status in describing objective physical reality (Osborne et al., 2003). From radical post-modernist perspectives, science's entanglement with external forces strips its findings of any special truth value (Koertge, 1998b), leaving "the notions of known fact, objective evidence, honest inquiry etc.,… ideological humbug" (Haack, 2003, p. 28). In her "once upon a time" rendition of science's evolving reputation, philosopher Susan Haack (2003) termed this a decidedly anti-science position and a breed of "New Cynicism." "Proponents of this new almost-orthodoxy…were unanimous in insisting that the supposed ideal of honest inquiry, respect for evidence, concern for truth, is a kind of illusion, a smokescreen disguising the operations of power, politics, and rhetoric" (p. 20). On the other side of the debate, scientists reply that such thinking is fundamentally flawed because it incorrectly uses a sociological interpretation of science to invalidate science's epistemological claims.[21] Though it may be appropriate to speak of the social construction of science as a process and an enterprise, its knowledge is empirically based and, so the argument goes, does not fall prey to the same kind of subjectivity.

In “Values of Science—Virtues or Vices?” science educator, Svein Sjoberg, taps the crux of current image problems when he argues, “young people may have sound reasons for rejecting science” (1997, p. 1). He presents, as object for debate, a table juxtaposing science’s stereotypic characteristics against their anti-thesis. His caricature has ideal science depersonalized; non-involved and detached; cold and rational; value-free, neutral, and objective; separating of self from reality; holding to a vision of an understandable and rational world without place for myth, ‘wonders’, miracles, and Gods; reductionist—understanding the whole through analysis of its parts; arguing deductively from basic principles; decontextualized and universal, theoretical and abstract, and systematic and consistent, with weight given to statistical evidence and the systematic testing of hypotheses.

It is unlikely that any amount of indoctrination about the creative elements of science will offset the above rather stodgy image of scientist as “unemotional, unimaginative, stolid, a paradigmatically convergent thinker” (Haack, 2003, p. 26). When, in curricular documents, scientists are assigned in broad, brush stroke fashion, the adjective of creative, I wonder if anyone has qualitatively or quantitatively assessed that claim. Surely, as humans, they are creative. And surely much of

[21] As Alan Sokal puts it (1998), analyses conflating two or more of ontology, epistemology, sociology of knowledge, individual ethics, and social ethics are typical of those who would tear down science's epistemological strength.

scientific progress has ensued from creative insight. Yet there seems considerable tedium, rigour, and repetition in science's careful inquiry and I must ask, How typical is creativity to science as against say the visual and performing arts, areas where culture is quite content to bestow that adjective. Indeed, as Sjoberg states, "we should not take to 'oversell' science with unjustified aims, claims and promises" (p. 13). It is an approach destined to backfire.

We can and should present a truer-to-science image. Sjoberg observes that the values or traits labeled 'ideals of science' draw largely from 'hard science' like physics and are generally more 'male' than 'female' (p. 8). In my own experience with student science fair projects, inquiry into, for example, the effect of sleep deprivation on exercise heart rate was looked upon less favourably than more atomistic type investigations like the relative strengths of three brands of tissue. The judges were practicing chemists from a local army base, all of them male. Surely we can do better in conceptualizing a broader and more relevant understanding of science to students.

In contrast to idealizing science's worldview, Sjoberg promotes educational approaches that inherently and overtly respect the integrity of learners and their other-than-scientific cultures (see Aikenhead, 2001 & Costa, 1995) by presenting science as a sub-culture—useful when the situation warrants it. In this, students "do not need to change their world-view, belief system and ways of behaving and thinking" (p. 8), but they can be taught to draw from science to inform collaborative understandings in social contexts.

Gerald Holton's views (1992) afford a poignant counterpoint to Sjoberg. Here we find an example of Susan Haack's Post-Kuhnian version of "Old Deferentialism" that adds "'incommensurability' and 'meaning-variance' to…obstacles to be overcome…[while retaining unbridled confidence in not only] the rationality of the scientific enterprise, but also of the power of formal, logical methods to account for it" (2003, p. 20). Holton presents lists, notably similar to those of Sjoberg, to compare science against non-science. However, according to Holton, the second list, as the anti-thesis of science, heralds a major risk to society and must be suppressed: In its "counter-worldpicture, one that would dismiss the [first] list above merely as 'scientism'" (p. 121) lie the revolutionary roots that undermine science's authority and threaten to return us to a dark age. In Holton's hands, this dangerous, idealized counter-vision to science is subjective, qualitative, personalized, ego-centred, sensualistic and concrete, and substantive rather than rationally instrumental. It places a premium on uniqueness and is neither meritocratic nor elitist, but rather accessible to all. It is purpose- or mystery-oriented, faith-based, authoritarian, and disinterested in tests of falsifiability (p. 121). Holton notes that "Goethe's anti-Newtonianism, Blakes Visionary Physics, the 'Aryan' science in Germany, the belief system of the 1960s counter-culture, the anti-science campaign associated with China's 'Cultural Revolution', and today's cults and beliefs involving faith healing, palmistry, and the like" (p. 122) can be characterized by the second list. He advocates prudence and action to oppose "the committed and politically ambitious parts of the anti-science phenomenon as a reminder of the Beast that slumbers below" (p. 125).

What are we to make of catastrophic predictions and perspectives extrapolated to imaginative extremes? How do people respond to remonstrations meted against them that denigrate, as less worthy, the very emotional and spiritual elements of humanness that make them feel most alive? What images of and about science do these reactions foster?

Still there are spaces between the cynical and deferential images and promising signs that we are approaching a between-the-extremes way—a way that also resists the restricting surety of a straight and narrow mid-line. Haack advocates "Critical Common-Sensism" to get us out from the quagmire of "incompatible conceptions of sociology of science…so inextricably intertwined" (p. 181). This perspective acknowledges

> that observation and theory are inter-dependent, that scientific vocabulary shifts and changes meaning, and that science is a deeply social enterprise; but sees these, not as obstacles to an understanding of how the sciences have achieved their remarkable successes, but as part of such an understanding. (p. 23)

Van Dijck (2003) focuses on the "many cultures (professional, disciplinary, global, ethnic) involved" (p. 185) in the production and dissemination of science knowledge. He directs us toward "an open-ended, negotiated, and negotiable arena of meaning construction" (p. 186) that involves the consumer in dialogue around science and technology.

Fortun and Bernstein's *Muddling Through* (1998) proposes a beginning set of terms meant to invoke the broad middle regions bridging paired extremes. Between "real" and "constructed" these authors place "judging;" between "experts" and "communities", "pluralism;" and, in like manner, "muddy," "crafted," "kludged," "charged," "contingent," "robust," "ambiguous," and time-dependent "realit*t*y" fill the middle spaces between "transparent/opaque," "elegant/messy," "clever/klutzy," "neutral/interested," "free/driven," "objective/subjective," "certain/uncertain," and "present/absent" (p. 275). In this, the "Culture of the Third," yes and no, both and can, and neither and nor co-exist. Indeed, in the spaces spanned by C.P. Snow's 1959 unbridgeable cultures of the first (the natural sciences) and the second (the humanities), Fortun and Bernstein posit a third alternative, encompassing space and edges, where science as process and infrastructure practices its rationality of experimenting, articulating, powering/knowing, and judging.

> The Culture of the Third…is a world of symbiogenesis, a developmental-evolutionary system vitalized by both nuclear (reason, logic, science) and cytoplasmic (history, politics, culture) forces. It is a world not simply of interactions between these elements, but fusions, confusions, and profusions of them: wonderfully and woefully complex systems of muddy hybrid components that always present challenges and questions along with products and results. (Fortun & Bernstein, 1998, p. 277)

In short, this new image presents science as a particular complex system that draws from other cultured systems alongside its distinguished inquiry methods about the complex world to act within and upon that same world. Its unit or agent of conceptual change is no longer the individual scientist, but increasingly, communities of scientists with/in society (Duschl, 2000, p. 200). And cognizant that "there are no observerless observations” (Davis & Sumara, 2005, p. 314) and that “descriptions of the universe are actually part of the universe” (p. 314) science gains valuable self-awareness to guide its ongoing and shared inquiry.

> Among scientists, current discussions of the natures of scientific inquiry and scientific fact are coming to be oriented by a realization that the cultural project of knowledge-making must be understood in terms of the complicity of the researcher in knitting the fabric of relations through which knowledge claims are rendered sensible and significant (see, e.g., Maturana, 1987; von Foerster, 1995; Latour, 1996). (p. 314)

Thus, when dealing with science in society we concern ourselves with a complex system whose nature and interactions do not reduce to simplified linear relationships of the “inadequate literacy” type. Complex systems are multi-leveled, nested, unpredictable entities for the reason that they unfold in recursive elaboration into “collectives that come to exceed the possibilities of the agents that comprise them” (p. 313). Accordingly, they “must be studied at the levels of their emergence” (p. 313)—a condition that returns us to the intent of the current study, for the images of science in culture constitute visible artifacts of emergent science. Notable promise for learning about public understandings of science resides in this emergent level of science-as-culture—where the “meaning making that we call science happens in a way that is distributed…spatially and temporally…. through science fiction, …through laboratory work[,] …in hospitals, …in advertising, and …in schools” (Weinstein in Aikenhead, 2000, p. 254).

Before proceeding to the proposal proper, there remains one last group of studies to consider: those seeking to assess science's images as these exist in the minds' eye of select groups of individuals, in the following cases, students. While "many previous studies of the nature of science have compared students' responses… with what are taken to be normative views" (Driver, Leach, Millar, & Scott, 1996, p. 141), a contrasting ideographic approach characterizes the two comprehensive studies that follow. In the ideographic approach, one that I hope to emulate, the researcher seeks to understand and characterize representations on their own terms, rather than simply judging their level of compatibility with pre-specified norms. Given past dominance of a public and student deficiency paradigm, the ideographic, or non-normative, approach to studying public understanding of science is relatively rare. As such these studies are gems that complement each other in depth and breadth. Sjoberg, Mulemwa, & Mehta's sweeping international project surveyed the images about science of over 9000 students spanning 21 countries (Sjoberg, 2000), while Driver et al. (1996) conducted in-depth qualitative studies of *Young People's Images of Science* in the United Kingdom. The next section focuses on their findings.

Students Images of the Nature of Science

Sjoberg, Mulemwa, & Mehta's cross-cultural project involved more than 60 researchers from nearly 30 countries in assessing the images of science held among classes of mostly 13-year old students. The pupils completed selected-response and open-ended questions about their science-related interests and experiences and their perceptions about science in action, scientists at work, and themselves imagined as scientists (Sjoberg, 2000). Among other things, the findings highlight interesting cultural and gender differences.

Overall, “the *image* of science and scientists is more positive among children in developing countries than in the developed countries. Children in the developing countries seem to be eager to learn science, and for them, scientists are the heroes” (p. 185). Children in more affluent countries, considered science, and school in general, a tedious duty imposed on them, while in developing countries, and especially among girls in these countries, learning science is a privilege—a positive option not open to everyone. Consequently, in richer countries students showed low to moderate interest in learning about science topics, with boys more interested than girls; whereas, in developing countries, the pattern was the reversed: interest was high, but with girls expressing more interest than boys.

Variations in images held about science and scientists reinforce these interest patterns. In industrialized nations, children’s drawings and writings of scientists followed the standard stereotype (with the occasional mad scientist) of a male, bald-headed, bearded, and in a lab coat working in a laboratory amongst test tubes and other symbols of research. Consistent with previous studies (Solomon et al., in Driver, Leach, Millar, & Scott, 1996, p. 47), few pupils in western countries mentioned scientists in the context of someone helping others. In stark contrast, children in developing countries saw scientists as “the servants and heroes of society”, describing them as “brave and intelligent, …helping other people, curing the sick, and improving the standard of life for everybody” (p. 182).

Sjoberg suggests that the skepticism and negative images of science and scientists in western societies reflect an understandable feeling of alienation from what children "perceive as the culture, ethos and ideals of science as well as the possibly frightening uses and misuses of science and technology in modern societies" (p. 184). Accordingly, he suggests a need for greater attention to Aikenhead's (2000) cultural border crossing for students in western societies.

In terms of gender differences, industrialized nations followed the Norwegian profile where boys outnumbered girls in invoking science fiction (boys 6%, girls 1%), cruelty or gruesomeness (boys 11%, girls 2%), and technology (boys 36%, girls 0%) when describing scientists. In "me as a scientist," girls were more likely to see themselves involved with medicine and health (girls 37%, boys 18%) and environment/pollution issues (girls 15%, boys 9%) (p. 182). In Nordic countries, Sjoberg found that able, confident girls deliberately chose to avoid science and engineering and that those choices seemed to be based on value orientations and emotional and personal factors.

Across the entire sample, when students rated their interest in variations of context on the same science content, notable gender differences emerged. For example, 21 percent more boys than girls selected "acoustics and sound" as an area of interest, while 12 percent more girls than boys expressed interest in the same content re-contextualized as "sound and music from birds and other animals" (p. 180). In general, girls preferred topics related to life, aesthetics, personal issues, and earth science. Thus, if gender equity in science education is a national concern, it is important to analyse possible biases in the contextualized images of science as presented in curricula, textbooks and classroom teaching.

In reviewing the literature on students' conceptions of scientific work, Driver et al.(1996) observe the prevalence of a naïve inductivist view of science. Students generally imagine "scientists as making discoveries about the world through careful observation" (p. 49). Students seem to hold a range of images of scientists simultaneously. In a large-scale Canadian survey in 1987, (Ryan in Driver et al.) the majority of students thought that scientists were "logical, methodical, analytical, and open-minded" (p. 55), both by training and in everyday lives.

The image of science and scientists emerging directly from the work of Driver et al. with 9-, 12-, and 16-year old students in northern England reinforce stereotypic western images, but their prevalence diminished with age. In general students associated science with questions about physical and biological phenomena, but not social phenomena—although older students drew attention to the importance of scientific work in addressing societal problems. In that capacity, science was primarily considered a provider of solutions to technical problems but minimally implicated, if at all, in controversial issues of socioscientific nature. Furthermore, the social nature of science itself was farthest from students' minds. They saw scientists as solitary investigators whose integrity followed from both necessity and personal altruism as opposed to socially constructed mechanisms of influence or control over research programs. Any conflicts or inconsistencies in science were attributed to either insufficient data or researcher bias.

Driver et al. used probes to prompt student dialogue, in dyads, about the nature of relationships in science between observation, evidence for correlation and causation, and the role of theory. As was found in their literature review, a naïve inductivist understanding of science prevailed, especially among younger students. In most cases, students saw explanations as linking observable features, either causally or as empirically derived generalizations. Notably, inquiry and explanation, conceived as the positing and testing of models and theories, was uncommon at any age with very few of even the 16-year-olds suggesting such notions about inquiry.

Why This Study Now?

> The twentieth century began with nature divided into physics, chemistry, biology and geology by an emerging community of scholars calling themselves scientists, but the century ended with nature viewed as a transdisciplinary collage by communities of engineers, technologists, scientists and funding agencies (Latour 1987). The twentieth century began with the high-school science curriculum divided into the content of physics, chemistry, biology and geology, taught to an intellectual and occupational élite. The century ended with a curriculum that adhered largely to its nineteenth-century roots, in spite of many innovative attempts to change it (Fensham 1992; Hurd 1998). (Aikenhead, 2000, p. 257)

I believe that we are at a vital turning point in the negotiation of western science (and approaching a consideration of other sciences) in society and the configuration of science in schools. The intensity and impetuosity with which scholars have engaged in science wars, the barrenness of a half-century of one-way efforts to "fix" public literacy, and a rising chorus of public skepticism railed against scientism's self-privileging status as the *prima facie* worldview, all, press for creative ways to re-imagine worn and sterile paradigms. The "high" science of the Enlightenment has, since its inception, burgeoned, relatively unfettered in ivory towers, into a mammoth western science enterprise. In the process it has gotten itself hugely out of step with its various publics, and the overlapping and intersecting societies and "low" science cultures inhabiting these publics.

Out of the crescendo of current discord and upheaval, a new breed of research has, over the past decade, gained momentum. Desiring to step outside the noise of seemingly pre-scripted and often tedious arguments and accusations, this research turns its gaze to public places for clues as to where and how science (albeit western science) resides there. Reminiscent of Thompson's depth-hermeneutical approach, the analysts in these studies attempt to do justice to the dual character of the cultural phenomena of western science: "that is, to the fact that these phenomena are symbolic constructs which are meaningful for the individuals who produce and receive [them]…; and… are always embedded in social-historical contexts" (Thompson, 1991, p. 395). While this emergent body of research is scattered across journals in sociology, philosophy, communication and media studies, cultural studies, popular culture, and education, the mother lode has found an accepting home in the *Public Understanding of Science* journal.

Now, in its 15th year, the journal is a principal hub for studies in social representations of science, with more than 50 articles about visible collections of artifacts that image this science in public places. Included are studies of, for example, image, myth, rhetoric, symbol, metaphor, and science discourse as these have played out in such public places as television documentaries, fiction film, postage stamps, hubble images, super-hero comics, the press, popular science texts, media discourse, children's science programs, science centers, and schools. With such a collection at hand, we do well to take stock—to systematically look backward that we might better adjust our forward gaze.

I propose to examine this group of studies on social representations of western science with an eye to emergent themes and patterns. Looking to make collective sense of what investigators have learned so far and to further inform inquiry in this fertile area, I ask, What typography, if any, can best gather, sort, and represent any themes and patterns found to exist across and in this particular genre of literature?

The proposed study is eminently timely. Until recently, there were not enough relevant studies upon which to consider building a typography. Moreover, given the numerous, varied, and seemingly contradictory images and perspectives evident throughout the above literature review, it behooves us to consider public forums directly, if only to inform western science about itself in culture—a condition I understand this science to be most anxious about in the first place. We cannot help people construct a viable understanding of the nature of western science by beginning from uninformed, presumptive, broad-sweeping generalizations about a nebulous public. If we are serious about teaching nature of science in schools, then at a minimum we ought to begin by improving scholarly understandings of western science (as appropriated in public spaces), its publics, and the interactions between these two. This approach not only promises to help western science learn about itself in a mirror of science-as-culture, it also has the potential to inform respectful border crossings between western science culture and other co-existing science cultures that collectively and synergistically move citizens to think, feel, act, and react. The proposed effort toward a typography of images offers at least a crude starting place upon which to further enhance communication and build shared understandings.

CHAPTER 3. METHODOLOGY

Having demonstrated, in chapter 2, the wisdom of foregrounding, via a typography of images, the landscape of public understandings of science, I now move to the question of method, and introduce phenomenography—a research approach, that seeks to map the qualitative landscape of perceptions about a particular phenomenon.

Situating Phenomenography

Phenomenography represents a new approach to qualitative inquiry. It emerged out of the investigations of a team of educational researchers at the University of Götenborg, Sweden, with the name first appearing in the published 1981 work of team member, Ference Marton. Now a theoretical and methodological research specialization, phenomenography began in the context of empirical studies into the nature of thinking. The Götenborg group looked to qualitative differences in approaches to learning to explain qualitative differences in the outcomes of learning (Marton, 2000)—a research direction that, among other effects, ushered forward the notions of deep and surface learning (Dall'Alba, 1996).

The methodology came forward in the 70s as part of a larger shift toward qualitative approaches to learning (Dall'Alba, 1996). In an atmosphere increasingly influenced by postmodernist sentiments and amidst a more encompassing evolution in the natural and social sciences, educational research of the 60s shifted from strong positivist roots in measurement and experimental design toward more interpretive, phenomenological, and constructed forms of inquiry (Lecompte & Preissle in

Dall'Alba, 1996). At the time, educational research was becoming less preoccupied with structures like curricula, learning spaces, and teaching strategies and more attentive to participant agency, including the behaviours and beliefs of the people of schools, notably students. Out of the general shift from structure to agency (Bogdan & Biklen, 1982 in Dall'Alba, 1996) and the particular shift from the content of learning to the processes of learning, phenomenography developed as a research programme aimed at investigating and mapping the experienced realities of students in learning tasks (Dall'Alba, 1996).

Over the past 30 years, the methodology has developed along three lines of inquiry: (a) the general aspects of learning; (b) the aspects of learning specific content particular to domains such as mathematics, physics, or economics; and c) "pure" phenomenography, which aims at describing the ways that people experience different aspects of their world (Barnard, McCosker, & Gerber, 1999; Marton, 1986). The proposed study falls under this third and least common category of "pure phenomenography".

The Conceptual Place of Phenomenography

Leibman and Paulston (1994), place phenomenography's methodology within a larger construct of *social cartography*[22], itself one of a class of five knowledge

[22] Leibman and Paulston (1994) describe three map types within social cartography: phenomenographic (research-based cartography of thought about a particular phenomenon); conceptual (less emphasis on research; format conceptualized by the map's creator to show all views of which the mapper's represents but one world view); and mimetic (simulates or imitates a reality; has the potential to be geographic in locating a variety of social or cognitive phenomena; a deconstuctionist mimesity challenges stability and privilege through mapped mimicry of alternative cultural perspectives)

communities[23], all of them sympathetic to postmodern sensitivities. By mapping the "plane of multiple social realities" (Leibman & Paulston, 1994, p. 233) the social cartographer makes "a shift in research from time to space, from facts to interpretations, from grounded positions to narrative readings, from testing propositions to mapping difference" (Paulston, 1999, p. 6). In mapping the ways of experiencing a phenomenon – for example science –the phenomenographer acknowledges, in the moment, the collective of multiple perspectives that co-construct the only reality we can know—that which we experience.

As a research approach, phenomenography is unique in its steadfast attention to describing the *range* of similar and different ways that people *experience* and understand phenomena in the world around them. A theoretical and methodological research specialization, its turn is scientific—as opposed to philosophical, or linguistic—and its method emphasizes a commitment to the phenomenon under investigation (Barnard, McCosker, & Gerber, 1999). It is "described often as contextual analysis [and] is sometimes referred to as empirical phenomenology or phenomenologically grounded empirical psychology (Alexandersson, 1981; Marton, 1981, 1986; Svensson, 1984, 1985, 1997; Svensson & Theman, 1983; Tesch, 1990)" (Barnard, McCosker, & Gerber, 1999, p. 213).

Though sharing with phenomenology the aim of revealing human experience and awareness by attending to and describing the world as experienced, phenomenography differs in origin and on several methodological, ontological, and

[23] Paulston (1999) identifies five knowledge communities in comparative education discourse that are sympathetic to postmodernist views: Postmodernist deconstructions; radical alterity; semiotic society; reflexive practitioner; and social cartography.

epistemological principles. Its emphasis is less on individual experience and pre-reflective thought than on gathering and *re*presenting collective meaning. Moreover, rather than taking a "first-order perspective in which the world is described as it is, phenomenography is phenomenal or experiential and aims to describe the world as it is understood" (Barnard, McCosker, & Gerber, 1999, p. 213). Thus, it does not engage in any sort of psychological reduction of data nor does it make claim to describe reality as separate from experience. And, while both phenomenology and phenomenography strive to explore, identify, and describe the *essence* of a phenomenon, the notion of essence takes on complementary meaning from one approach to the other. Whereas phenomenology sees essence as the singular *common intersubjective meaning* of a phenomenon, phenomenography captures essence by attending to the *variations in ways of experiencing* that people bring to a phenomenon (Marton, 1981, p. 180; Neuman, 1997, p. 65). Accordingly, descriptions in phenomenography focus on individual understandings, both in prereflective and conceptual thought alike. The final *outcome space* consists of *categories of description* that individually summarize the varying conceptions and that, when grouped, fairly depict the conglomerate of collected meanings ascribed to the phenomenon.

Methodological Goals

Phenomenography maintains "an epistemological perspective that concentrates on the *what* of thinking, the meaning people ascribe to what they experience" (Barnard, McCosker, & Gerber, 1999, p. 219) and the *how* of the structure of that thinking. To reiterate, the product of any phenomenographic analysis is the *outcome space*. In theory synonymous with the phenomenon, the *outcome space* embodies its essence in the sense that it holds and presents, in a non-weighted manner, the variations of perspectives or conceptions of the phenomenon as experienced. And, since we cannot know unexperienced reality, this variation on the phenomenon is, in essence, the phenomenon, or at least all of it that we can speak to. How can we make such a claim for findings typically arising from a limited sample of individuals?

A central premise of phenomenography, supported consistently in the tradition (Marton, 1986, p. 37), tells us that across individuals in a given collective, "a phenomenon appears, as a rule, in a limited number of ways…. [I]f 20 to 30 individuals are interviewed, and other people from the same population are interviewed later, there rarely appears any new way of experiencing the phenomenon" (Newman, 1997, p. 65). Thus, the *outcome space*, as derived under phenomenographic methodology should be a valid descriptor of the phenomenon because "the set of qualitatively different ways of experiencing a phenomenon is finite" (Marton, 1996, p. 186) and accessible through a sampling of the population. This is not to say that any given and valid *outcome space* is a static and complete entity.

For several pragmatic reasons, any outcome space is tentative—a work in progress representing only a partial understanding of the phenomenon under investigation. First, any constraints on the population from which the sample is drawn should limit the breadth of conceptions in the study's *outcome space*. Second, "in line with the principles of awareness underlying phenomenographic research, the outcome space… represents a relationship between the researcher and the data, i.e., the data *as experienced by* the researcher" (Åkerlind, 2002, p. 10). And though it need not be the *only* possible outcome from the data, it is one that can be argued for[24]. Finally, the very nature of human–world experience and the ongoing flux of ideas and perspectives—be they everyday, scientific, or philosophic—should remind us that the *outcome space*, and the phenomenon described thereby, though theoretically finite in space, is definitely not so in time (Marton, 1996). It can only be but a snapshot, however blurred, of a moving target.

Underlying Assumptions and Organizing Principles

The Faces of Variation

In an academic climate increasingly appreciative of the personal and social construction of knowledge, the Götenborg group studied the ways of thinking and understanding that people took to and from experiences. In particular, they interviewed students on their conceptions of learning in a reading comprehension task and compared these against learning strategies and type of learning attained. They found that people who are "better" at learning perceive the nature of learning in qualitatively distinct ways. Moreover, the relationship between approaches to learning in a reading task and the qualities of learning taken from the reading task held across other learning activities such as "essay writing (Hounsell, 1984), listening

[24] Whether the logical structure of the outcome space should emerge directly from the data or more explicitly from the professional judgment of the researcher is a debated matter of degree. "The final outcome always reflects both the data and researchers' judgments in interpreting the data" (Åkerlind, 2002, p. 10).

to lectures (Hodgson, 1984), and problem solving (Laurillard, 1984)" (Marton, 1994, p. 4425).

For the phenomenographer, the nature of a phenomenon is less captured in sameness of experience of that phenomenon than in its variance and the structure of that variance. To fully grasp essence, in a phenomenographic sense, one must examine the range of individual experiences (Marton, 1986, p. 41; Marton, 1996, p. 186). "The 'truth' about a horse, for example, is the sum of the observations of the horse-book writer, the jockey, the gambler, the farmer, the teenagegirl [*sic*], the veterinary" (Uljens, 1996, pp. 7-8). From this view, and consistent with the thinking of social cartography, any scientific picture of the world, including any science picture of itself, necessarily reflects but one of many experiences of science. As Uljens (1996) presents, from the standpoint of phenomenography, the scientific worldview gains no priority over folk-psychological description[25].

In explicating the nature and origin of phenomenography, Marton (1981) emphasizes two different perspectives that orient the kinds of research questions asked. The *first-order* perspective is most prevalent in educational research, according to Marton, and, it seems to me, in educational research about the understanding of science *qua* science literacy. It aims at describing various aspects of

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[25] Still, I am intrigued that Uljens so readily concedes privilege to science on pragmatic grounds. He argues "it is often the case that scientific description is more useful or effective than most folk-psychological theories" (1996, p. 8). I am moved to ask, Would usefulness and effectiveness not be largely a function of fit and perspective? Useful and effective in what manner of experience? As feminist Evelyn Fox Keller puts it, "As routinely as the effectiveness of science is invoked, equally routine is the failure to go on to say what it is that science works *at*" (Keller, 1998, p. 397)

the world. In contrast, the *second-order* perspective, attended to in phenomenography, aims at describing people's *experience* of various aspects of the world. Consider, for example, the questions "What is happening to the ozone layer?" and "What is the nature of science?" To answer these questions one posits statements about reality, as would be the case if one answered, "The ozone layer is diminishing" and "Science is tentative." In these first-order perspectives "we orient ourselves to the world and make statements about it" (p. 178). Alternatively, the questions, "What do people think about what is happening to the ozone layer?" and "What do people think about the nature of science?" for example, direct us to statements about people's conceptions of an aspect of perceived reality. Corresponding answers might be "There are people who think that the ozone layer is diminishing" and "There are people who think that science is tentative." The alternative questions orient us to different kinds of answers—second-order perspectives that address people's conceptions about the world (or their experience of it).

Phenomenography is dedicated to formulating questions of the second-order kind—questions that "do not try to describe things as they are, nor… [that even] discuss whether or not things can be described 'as they are'" (Marton, 1986, p. 33). Rather, phenomenography tries to characterize how things appear to people. And since human beings perceive and experience *things*, the descriptions of perception and experience must always be made in terms of their content. As a result, unlike traditional psychology, phenomenography does not seek "overarching laws of thought and perception that can be applied no matter what the situation or subject matter" (p. 32). Instead, phenomenography informs us about a known and apprehended world by focusing on “the *relations* that exist between human beings and the world around them” (Marton, 1986, p. 31).

To distinguish between first- and second-order perspectives should not be confused with making statements about the existence of reality or any separation between a supposed reality and our perception of it. Phenomenography rests on a non-dualist ontology (Marton, 1981, 1986, 1999; Neuman, 1997; Pang, 2003; Uljen, 1996). If we can only access the world through experience, then any separation of that which is experienced from the experience per se becomes impossible (Marton, 1996, p. 180). Thus, phenomenography neither posits, nor seeks to investigate, any “objective reality.” It cares not to examine, nor even question, “the ‘realness’ of a reality independent of our perception of it, … [or] the ‘realness’ of our experience of this reality” (Marton, 1981, p. 178). Indeed, how can one meaningfully talk about, or empirically examine, unexperienced reality?

Tracing to conclusion the notion that “people’s different ways of understanding or experiencing the surrounding world [scientific or everyday] is all there is” (Uljen, 1996, p. 113), we realize that, though we can compare different understandings with each other, any attempt to compare understandings of reality against reality itself is a problem.

> This means it is impossible to reach absolute truth about something—in principle…—since new interpretations are continuously made both by ourselves and by every new generation. In this sense reality *is* experience.

> Scientific truth is, according to this position, absolute[26] only in a relative sense (Uljen, 1996, pp. 112-113).

Phenomenography's methodology, being descriptive, empirical, and qualitative, "occupies a space somewhere between natural science (disciplines that deal with what we hold to be true about the world) and traditional social science (which seek to discover laws of mental operations and social existence)" (Marton, 1986, p. 32). In its original sense, it begins from the individually experienced everyday world, seeks "relational, experiential, content-oriented, and qualitative" (p. 33) categories of descriptions about people's conceptions of that world, and subsequently maps an *outcome space* to represent the variation, and hierarchy in variation, of ways of experiencing those aspects of the world.

This descriptive and methodological orientation (for representing variation in ways of experiencing a *particular* phenomena across a *various* public) has been recently recast as *the first face of variation* (Pang, 2003). In response to criticism about early phenomenography's somewhat "atheoretical stance" (p. 146), recent work extends theory about ways of experiencing—introducing to the research agenda a *second face of variation* (Marton, 1994, 1996, 2000; Marton, Wen, & Wong, 2005; Pang, 2003). Whereas phenomenography began with "questions about how to describe different ways of experiencing something," the new phenomenography asks, "what is the nature of the different ways of experiencing something described" (p. 146)? This reformulation shifts attention to more theoretical concerns about the nature of awareness and what it actually means to experience a phenomenon. Put

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[26] If indeed it can be considered absolute at all!

differently, if experience (i.e., accessed reality) and the phenomenographic interest lie in the relational subject-object space, then the first face of variation casts its gaze on the object thus experienced while the second face of variation attends to the experiencing subject. This second point of view takes a theoretical stance on structural and referential natures of awareness[27] asking, "What is entailed in a way of experiencing? What is the difference between ways of experiencing the same thing? And how might different ways of experiencing something evolve?"

The Object of Research: Experiencing and the Nature of Awareness

Much ambiguity has plagued phenomenography quite simply because the object of study has persisted as a rather vague entity with a seeming hodgepodge of interchangeable terms for naming it. Marton (2000) points out,

> during almost two decades we have done research about conceptions, experiences, views, perceptions and so forth, of phenomena, problems, situations, acts, events etc., without being very clear about what kind of entities 'conceptions of learning', 'apprehensions of children at play', 'understandings of understanding', 'perceptions of numbers', etc., are.… Because of this, phenomenography has been a rather elusive enterprise. (p. 102)

Still, this should come as no surprise. If phenomenography is consistent, why would it not admit multiple experiences of its very object of research—let us call it

[27] Awareness is here used in a specific phenomenographic sense and includes the "totality of a person's simultaneous experiences, her relatedness to the world" (Marton, 2000, p. 109). In experiencing the particular, "awareness" entails all of the unconscious and conscious knowings (present and past) that the subject concurrently bears in constituting the experience of that phenomenon.

"experience"—itself? Yet, at some point, phenomenography would have to turn on itself and ask, what does it mean to experience a phenomenon? The answer to this question is of course, crucial to the present project. It affords the theoretical means by which I can make explicit my object of research. Without such clarity, I would have difficulty delimiting and communicating the kind of data I seek about the relations between people and science from the body of information available.

In trying to describe relations between the individual and various aspects of the world around them, phenomenographers, according to Marton, (1981, 1986) permit manifestations "in the forms of immediate experience, conceptual thought, or physical behavior" (1986, p. 42). Allowing that the form makes a difference on the psychological level, phenomenographers assume a structural level unaffected by these differences (Marton, 1981, 1986). Marton (1994) emphasizes the interchangeable nature, in phenomenography, of the words experience, perceive, apprehend, understand, and conceptualize, etc. He does not deny differences in the meaning of these terms, but rather points out that the limited number of ways a certain phenomenon appears to us can be found and described in the phenomenographic sense, regardless of "whether, for instance, they are embedded in immediate experience of the phenomenon or in reflected thought about the same phenomenon,… [—that is, independently] of the differences between experience, perception, apprehension, understanding, conceptualization etc." (Marton, 1994, p. 4426). The acceptance of multiple manifestations of experience for phenomenographic analysis is pivotal to the present study. Without such acceptance I could not justify my intent to gather data from a collection of diverse studies from various disciplines that share a common research interest in public perceptions on the nature of science.

All of the above notwithstanding, the consistent admission of interchangeable terms for an object of research does confuse. In 1996, Marton announced his preference for the term "way of experiencing" as the object of research. As he argues, in leaning neither toward subject nor object in subject-object relations, the expression "way of experiencing" points to a relational place of being in the world and therefore feels a best fit with phenomenography's non-dualist ontology. To consider a "way of experiencing" is to encompass the multiple nuances of experiencing, including, for instance, conceptualizing, perceiving, apprehending, understanding, and imagining. Though all the aforementioned terms appear throughout the phenomenographic literature, the terms "way of experiencing, conceptualizing, and perceiving," in that order, prevail.

If the goal of phenomenography is to describe ways of experiencing phenomena, what then is a phenomenon, and what constitutes a way of experiencing it, in the phenomenographic sense? Phenomenography adopts the phenomenological sense of a phenomenon as "the thing as it appears to us", which contrasts with the Kantian *nuomenon*, "the thing as such" (Neuman, 1997; Marton, 2000). If it appears to us, then it is discernable and if we can speak of it, then the phenomenon, of which we speak, must be a humanly experienced, identified, and communicated aspect of the world[28]. At the same time, owing to multiple ways of experiencing, a

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[28] A particular phenomenon is that aspect of experienced reality about which there exists some degree of consensual human awareness. A group of at least two individuals have identified it as such; that is, someone discerned (experienced) it and

phenomenon is theoretically the "complex of all the possible ways of experiencing it, [including] those found already and those not yet found as well" (Marton, 1997, September, item 10). The research product is an *outcome space* that approximates the phenomenon in the form of a logically structured complex of different *categories of experience* as these are experienced by the researcher through phenomenographic analysis of the individual ways of experiencing, evidenced in the data.

In phenomenographic theory (Marton, 1996, 1997, September, 1999, 2000; Neuman, Pang, 2003), a *way of experiencing* (i.e.: a particular category of experience) entails a simultaneous discernment of invariance against a background of variance[29] of distinguishing characteristics across time and space. An *object of focal awareness,* otherwise known as a *theme*, or phenomenon attended to, enters experience as against, and embodied in, past and present contexts concurrently. A phenomenon enters awareness and becomes experienced only when it can hold together as a distinguishable thematic whole against both the backdrop of related experiences of characteristics and phenomena (termed the *thematic field*) and other experiences of seemingly unrelated characteristics and phenomena (termed the *margin*). In this way, humans experience the discernment of an object, from that which it is not, according to critical distinguishing features. The discernibly invariant

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attempted to communicate their awareness to another (else we would not know about it to name it or study it (*cf.* Berger & Luckman).

[29] All things being relative, we do not visually experience motion on a train except as against a backdrop of scenery that changes through the window. If we focus on the train, holding it still or invariant in our minds eye, then it is the scenery that appears to vary. Conversely, if we focus on an aspect of scenery, affixing it in our minds eye, we experience our motion relative to it. For discernment to occur, a distinguishing characteristic (even if it is constant change) has to become fixed, experienced, and attended to against a backdrop that is seen to vary on that characteristic.

features of a phenomenon, that render the phenomenon recognizable, are the delimiting and internally-related characteristics that distinguish the object against its backdrop of variance—variance simultaneously experienced both in manifestations (past and present) of the object and in the context (relevant or not) within which the object presents. To be distinguishing, these features must afford sufficient cohesion (internal logic) across experiences to render the phenomena whole enough to hold together and different enough to stand apart from its context. This means that for someone to experience a phenomenon or a particular aspect of reality, as part of a larger class, for instance homeopathic explanations as scientific, that person simultaneously experiences and discerns a set of defining features of homeopathy as distinct from non-discerning or neutral features, and they do this at the same time as they experience homeopathy against the entire set of features experienced as science versus non-science life experiences. To acknowledge the above theory of awareness is to accept the complexity of awareness and experience, and to recognize the futility in trying to pigeonhole people according to generalized principles of perception about science. Science has multiple and shifting characteristics that appear in various ways to various individuals in various circumstances. Better then to attend to a mapping of perceptions that exist.

The awareness that we bring to bear in experiencing, be it conscious or not, entails both *structural* and *relational/referential* aspects. The structural elements of a phenomenon refer to the "how" of the phenomenon's assemblage. It describes which aspects are included in the phenomenon and which are not, as well as how the various aspects relate to each other and to non-aspects in a defining and delimiting way, so as to render a *sense of wholeness* about the construct. In phenomenography,

> knowledge is whole in the sense that we have knowledge that is derived from related entities having the character of forming wholes even though ultimate understanding may be incomplete…. [M]eaning is made up of parts to form wholes that may, or may not, reflect shared meaning. Thus, there are always a number of differences in the way in which we can understand the world, and these differences arise from the whole, which is derived from the context of experience. (Barnard, McCosker, & Gerber, 1999, p. 218)

Whereas structure describes the form and shape of awareness in conception, the relational (Neuman, 1997) or referential (Barnard, McCosker, & Gerber, 1999) elements of awareness imbue a phenomenon with meaning. They describe the "what" of the phenomenon. At the heart of the conception of a phenomenon, the "what" or meaning is clearest and most accepted as a commonplace understanding. "Commonplace conceptions are the living beliefs that are repeated and used by people as criteria for judgment. They represent individual and group hierarchies of values, beliefs, and philosophy" (p. 213). At the boundaries of the *internal horizon* of the phenomenon, meanings become fuzzy, explanations vague—the notion of the phenomenon holds together less decidedly. Here, when interviewed, participants broach their boundaries of experience with the phenomenon and enter into the *external horizon* within which the phenomenon sits. It is at these boundaries, that the skilled interviewer prompts conscious attention to otherwise prereflective understandings and experience.

Thus, the phenomenon in question, identified as the object of focal awareness or theme, has an identifiable structure. That structure is an assemblage built through experiences of invariance against variance of both defining and non-defining features. It is this cohesive structure that Marton terms the internal horizon. In the internal horizon, individuals express the greatest certainty regarding their understandings of the phenomenon in question. Here, the entity feels whole and bears significance because the structure is held together by meanings experienced and relationships perceived—these constituting the relational side of awareness. “The internal horizon refers to the parts and their relationship, together with the part-whole structure discerned therein” (Pang, 2003, p. 148).

Likewise, humans tacitly experience a thing as a thematic entity set in the historical and spatial context of that which it is (invariance perceived) as against that which it is not. The thematic field consists of all aspects of the experienced world that are related to the object and within which the object is embedded. Marton assigns the term 'margins' to mean the remaining universe of all thematic fields that coexist but are perceived as unrelated to the phenomenon in question. “The external horizon of an object… encompasses the thematic field and the margins as well. The field is related to the theme by dint of relevance” (Marton, 2000, p. 114) and the entire fluid structure of internal and external horizon is relationally defined and redefined according to the subject’s ongoing experience of the world. “According to Marton and Booth (1997), the structural and referential aspects of human awareness are the dialectically intertwined aspects of a way of experiencing a phenomenon” (Pang, 2003, p. 149) and they define what we take that phenomenon to be.

In summary, phenomenography understands a way of experiencing a phenomenon in terms of both the features of individual awareness, and the dimensions of variation that are discerned and simultaneously focused upon. "Correspondingly, the different ways in which different phenomena can be experienced, the collective mind, reflect the differences in the structure and organization of awareness" (Pang, 2003, p. 152). The new phenomenography examines "both the variation among different ways of experiencing something as seen by the researcher, and the variation among the critical aspects of the phenomenon itself as experienced" (Pang, 2003, p. 152). Important to the project at hand, "a complete characterization of a conception must include the distinction between expressions that predominantly reflect a referential aspect of understanding and expressions that predominantly reflect a structural aspect" (Barnard, McCosker, & Gerber, 1999, p. 216).

Marton (1996) offers the following succinct description of the basic unit of phenomenography as "experiential, non-dualistic, an internal person-world relationship, a stripped depiction of capability and constraint, non-psychological, collective but individually and culturally distributed, [and] a reflection of the collective anatomy of awareness, inherent in a particular perspective" (p. 172). Resting on these understandings, the driving force of phenomenography is the belief that "to make sense of how people handle problems, situations, the world, we have to understand the way in which they experience the problems, the situations, the world, they are handling or acting in relation to" (Marton, 1996, p.178). This owes to the appreciation, from the phenomenographic stance, that "the capability for acting in a certain way reflects a capability for experiencing something in a certain way" (p. 178). For that reason, and in the context of the current study, if one wishes to understand people's actions and reactions to science, one should, as a first step, look to mapping the various ways in which the notion of science is experienced, conceptualized, and thus seen to exist, in the world. Phenomenography is a best fit for the current thesis question.

The Phenomenographic Approach

Typical and Necessary

What is it like to carry out phenomenographic research, typically and necessarily? Owing to roots in educational research practice about student understanding, yet neither intrinsic nor necessary to the methodology in theory, the interview remains the primary method for phenomenographic data collection (Åkerlind, 2002; Bernard, McCosker, & Gerber, 1999; Marton, 1986). Indeed, when it comes to method, there seems as much, if not more, written about the phenomenographic interview as about the analysis of data. Moreover, even discussions of data analysis assume data in the form of transcribed interviews. At the same time, writings on methodology consistently preface discussions of interview data with the proviso, almost as a footnote, that the source of phenomenographic data need not be the interview (Åkerlind, 2002; Barnard, McCosker, & Gerber, 1999; Bowden & Walsh, 2000; Dall'Alba & Hasselgren, 1996; Gunn, 2003; Marton, 1981, 1986). As Barnard, McCosker, and Gerber (1999) put it, though there is no single procedure specified, "the starting point is always the data" with methods "selected and altered in relation to the type and nature of the phenomenon under investigation"

(Barnard, McCosker, & Gerber, 1999, p. 215). Thus the interview, though typical, is not necessary to the phenomenographic project. What then is necessary? What can be adapted from interview guidelines? And what type of data is needed for phenomenographic analysis?

To be sure, the kind of data sought must contain potential answers to the phenomenographic question posed. And the formulation of the research question must embody a phenomenographic understanding of both the multi-experiential nature of phenomena and the meaning and structure of awareness. That is, the data must individually, and as a collective, contain aspects that point to the referential "what" of experience—the meaning of the phenomenon as experienced, together with the structure of "how" meaning is organized. Relevant information can be found in a number of ways: (a) dialogically through interviews and group discussion, (b) through the study of artifacts such as drawings, writings, and actions that express the thoughts of individual subjects, or (c) through discourse analysis of qualitative studies of the aforementioned types (Marton, 1981, 1986).

Nearly all phenomenographic exemplars come in the first type. Very few studies rely solely on artifacts of experience; in fact I have located only two: Marton (1986) speaks of Wenestam's 1982 analysis of children's drawing; and Gunn (2003) claims to apply phenomenographic methods to medieval writings, though I am unconvinced that her approach actually qualifies as phenomenography. Finally, I know of no studies that take the course I propose here; that is, using discourse analysis of qualitative studies of a phenomenon as the primary data source.

A key challenge of drawing phenomenographic data from multiple studies of a phenomenon lies in the potential incongruencies of research questions and vantage points across the spectrum of studies. At the same time, breadth and diversity of perspective ought not be avoided or homogenized for the sake of ease of study and representation. Indeed, the phenomenographic approach values such multiplicity precisely because the method strives for an *outcome space* that fairly represents variation. Thus, drawing phenomenographic data through discourse analysis is potentially as challenging as it is fruitful. Notably, the qualitative studies of ways of experiencing science found the *Public Understanding of Science* journal exist in well-defined research contexts across many particular publics.

Keeping in mind that the aim of phenomenography is to depict variation in experience, a heterogeneous sample tops a representative one in the usual sense of representation. In terms of the frequency of distribution of ways of experiencing, phenomenographers do not seek outcomes that are generalizable from sample to population. Instead, results that are true to variation in experience aspire to generalizability in the *range* of ways of experiencing. “Even with less similar groups of people, the meanings and dimensions of variation that emerge from the sample group should still be relevant, but are likely to constitute a less complete representation of the range” (Åkerlind, 2002, p. 12). Thus, the phenomenographic bent toward breadth of representation is consistent with and strengthens the proposition that analysis of studies in the *Public Understanding of Science* journal should yield a valid *outcome space* for the phenomenon of science as experienced globally.

At the same time, and owing to the diversity of input, there may be more gaps in the final mapping than one might find in a more localized undertaking. This should not however significantly compromise the quality of the research outcome, because, as discussed previously, a valid outcome space is an emergent entity that makes no claims to being the "right" interpretation, but rather strives for a defensible one (Åkerlind, 2002, p. 13). Phenomenography attempts to portray in an instance in time and space the nature of experience of a phenomenon that is by nature changing and inexhaustible. Thus, provided there exist sufficient and comparable qualitative studies investigating the understanding of science from different perspectives, the proposed undertaking should be both doable and advisable.

Indeed, from the beginning, Marton (1981) pointed to research of the phenomenographic type that, though not so named, already existed in and across a variety of different disciplines and schools of thought; for instance, psychology, anthropology, sociology, and educational research. He saw these various pools of research as untapped sources of experiential, qualitative, content-oriented and interpretative descriptions that characterize reality as experienced by different people in different situations and that thematize the individual's world over the individual (Marton, 1981, p. 189). As though speaking directly to the present proposal, Marton urges that "descriptions which have been arrived at from the second-order perspective can and should be brought together, irrespective of the source of variation they represent, the discipline to which they belong or the 'school of thought' from which they stem" (Marton, 1981, p. 190).

With growing interest in the public understanding of science, and with the existence, since 1992, of the multi-disciplinary journal of the same name, there is a ready pool of data for mapping the phenomenon of science as experienced. At this point, the body of available qualitative research should be rich enough to meet the needs of the proposed phenomenographic analysis.

Certain guidelines, for formulating the design and conduct of phenomenographic inquiry have solidified over the past decade. Many relate to the phenomenographic interview (Ashworth & Lucas, 2000; Barnard, McCosker, & Gerber, 1999; Marton, 1981, 1986), but much of that information is transposable to the present context. The next section considers how these guidelines inform the present project.

Guidelines for Conducting Phenomenographic Research

I begin with a reminder that phenomenography is defined in terms of the object of research. It is substance- as opposed to method-oriented—a condition that in practical terms means its approach cannot be laid out in clear-cut algorithmic fashion (Marton, 1986). Rather, underlying assumptions and organizing principles must guide the method through an unfolding of ways of experiencing and categories of those ways of experiencing. From the beginning, Marton (1986) stressed the discovery nature of analysis whereby the phenomenographer seeks a set of categories or meanings that “cannot be known in advance but must *emerge* from the data, in relationship with the researcher. [T]here can be no algorithms for a process of discovery” (Åkerlind, 2002, pp. 3-4). Still, certain research principles have been derived from, and continue to contribute to, method.

As stated above, much attention is given to the formulation of interview questions and the interview process. Yet one neither dialogues with an artifact, nor with a body of research projects as the present thesis proposes. At best I can extrapolate guidelines for interviews into the current context, recognizing that many simply do not apply.

In interviewing students, Ashworth and Lucas (2000) emphasize the need for the researcher to bracket or set aside presuppositions in order to register fully an Other's point of view (p. 297). These authors make the case for using empathy to assist bracketing. In the context presented, empathy "involves imaginative engagement with the world that is being described" (p. 297). It "requires a detachment from the researcher's lifeworld and a opening up to the lifeworld of the student" (p. 297). Applied to the proposed thesis, evidence of bracketing, where applicable, should characterize the studies chosen for phenomenographic analysis. The findings, which I analyse, must be couched in a context that allows me to enter into the experiences of the participants, at least to the extent that I am able to, myself, experience the meanings they ascribe to science.

Keeping in mind the importance of bracketing, Ashworth and Lucas (2000) offer nine directives for the conduct of phenomenographic research. These complement Neuman's (1997) five guidelines for using phenomenological reduction to minimize predefinition and thereby enhance research reliability. The following sections summarize the relevant principles that will guide the present proposed study.

Orientation to the research question.

Throughout the research process, the researcher must continuously orient herself to the phenomenon through a clear formulation of the research question. Central to reliability is a clear definition of the object of research, as experienced by the researcher. A clear definition enables the conceptualization of appropriate questions put to the data and the formulation of an *outcome space* true to the phenomenon under study (Neuman, 1997). Phenomenographic theory will direct the definition of the object of research and the formulation of questions to target and delimit the object of research from the body of literature contained, first in the *Public Understanding of Science* journal, and second in the subset of selected relevant studies.

A clear definition of the object of research should not be confused with clear expectations for outcomes. In fact, with the exception of research that builds on previously established categories of description, investigations aspiring to map the *outcome space* of a phenomenon not previously examined should be open to all possible ways of experiencing the phenomenon to be studied (Åkerlind, 2002).

General guidelines for selecting appropriate studies for data collection. To qualify for analysis, the selected studies must be qualitative in nature[30], show evidence of either bracketing or researcher self-disclosure (where the data was

[30] In my experience, quantitative studies in the realm of the public understanding of science fail to tap the breadth of public images or experiences of science. Instead, they assess the degree of public ascription to perceptions pre-set by the researchers conducting the study. As such they are not sufficiently open to admit the full range of perceptions out there. Moreover, such studies tend to a deficit view of public science literacy, infusing this deficit perspective into their measurement scales of attitude and understanding. For these reasons, it is important that the data set derive from studies sufficiently open to perceptions as these exist, unaltered, in the public domain.

obtained dialogically), attend to public conceptions about the nature of science or an aspect of science featured in the particular study, and provide sufficiently detailed information on context, meaning, and perspective so as to minimize any misconceptions and misapplications of particular research findings in my own interpretation (experience) of the data.

My selection of studies should avoid any personal presuppositions about the nature of science or about the nature of conceptions about science that are held by particular schools of thought. As much as possible, the choice of studies should not limit variety of experience of science.

That said, an inherent and fundamental challenge persists across any studies taken for present analysis. For the most part, qualitative studies on public perceptions of science begin from a researcher-defined instance of science and move to an analysis of perceptions of that localized instance. Thus we encounter huge diversity in the aspect of science that is reflected upon. This might create the effect of multiple studies on multiple phenomenon—each a subset of science in public, as determined by the researcher—such that commonalities of experience fail to emerge. However, such a finding, should it occur, still furthers understanding of the complexity of public perceptions of science and would therefore still be valid.

Guidelines for analysis. Analysis and presentation of outcomes should be restricted to *descriptions* of ways of experiencing the phenomenon. "The researcher should not only identify *what* the interviewees experience but also *how* they experience this 'what'" (Neuman, 1997, p. 66). Put differently, analysis begins with a search for understanding the referential aspects of the phenomenon (i.e., what is thought about science) and expands toward an understanding of its structural aspects (i.e., how conceptions about science together contribute a sense of wholeness and how they delimit science from non-science). Researchers should *not* attempt to analyse *why* experiences appear the way they do (Neuman, 1997). Phenomenography is descriptive by nature and any theory about the why of thought cannot arise from the method proposed.

In the beginning of analysis, "all aspects of the experiences observed should…be seen as equally important in order to faithfully interpret the essential aspects of ways of experiencing the phenomenon" (Neuman, 1997, pp. 65-66). The researcher must continually adapt the different possible interpretations that appear when reading the data until a basic meaning structure has stabilized. "Analysis should avoid premature closure for the sake of producing logically and hierarchically-related categories of description" (Ashworth & Lucas, 2000, p. 305). Likewise, the researcher should not ignore aspects of the data in an effort to ensure a logically structured *outcome space* (Åkerlind, 2002). Rather, any incongruous data should be brought to the fore in some capacity and presented as the conundrum that it is. Finally, the researcher should take care not to superimpose preconceived notions onto the data. That said, "the greater the researcher's knowledge and varied experience of the phenomenon, the better their ability to constitute a logical and meaningful structure to the outcome space" (Åkerlind, 2002, p. 11). Thus, an extensive understanding in the review of the literature should strengthen analysis provided the researcher does not to let previous knowledge compromise an open-mind.

Steps in analysis: Commonalities and variation in practice. Analysis begins with a search for meaning, or variation in meaning, across the data sources—in the present case, studies that describe second-order experiences of science. Interpretations at this level attend to both the varying contexts of the reported experiences and the research context as articulated in definitions of the object of research and as reflected in valid questions put to the texts. Though to some extent concurrent with a search for meaning, the search for structural relationships between meanings both follows and supplements a developing appreciation of the ways of experiencing embodied by the data. The *outcome space* for the phenomenon – that is, the field of categories – unfolds as qualitatively different characterizations of experience come into view, shift, and solidify according to similarities within and differences between categories. All the while, the researcher focuses on the data sources and the emerging categories of description *as a set*, rather than as individual entities (Åkerlind, 2002, p. 3). The researcher minimizes predetermined views, avoids rapid foreclosure in solidifying categories, and willingly adjusts thinking in accord with insights that become visible in the ongoing comparison between and within data and emerging categories (Åkerlind, 2002; Marton, 1986).

In practical terms, it is generally impossible to hold all possible aspects of 20 or more data sets, be they interviews or qualitative studies, at one time. The amount of each data set that the researcher considers at one time varies in practice. Some phenomenographers begin by considering and re-considering whole data sets—or at least large chunks of them—until a diffuse, global idea about the phenomenon takes shape (Neuman, 1997). At times, researchers begin with a preliminary sample of 5-10 transcriptions before bringing in the full set (Akerlind, 2002). Others begin by selecting smaller excerpts seen to represent particular meanings (as determined in the context in which they appear) and combine these for analysis in one decontextualised pool of meanings (Marton, 1986).

In any case, the overall approach is a strongly iterative and comparative one of continual sorting and resorting of data. Researchers group and regroup whole data sets, key portions, or selected quotes according to perceived similarities and differences along varying criteria. Sometimes "the groupings precede explicit description of the similarities and differences, at other times the groupings are made according to tentative descriptions for categories, as a checking and validation procedure" (Akerlind, 2002, p. 3). Phenomenographers test categories against the data, adjust, retest and adjust again, until fewer and fewer changes are needed and the whole meaning structure stabilizes (Marton,1986).

Research outcomes. "By separating forms of thought both from the thinking and from the thinker" (Marton, 1981, p. 196), the phenomenographer ultimately derives categories of description to characterize the perceived world (or at least fragments of it). The collection of categories of description constitute the *outcome space*, which represents "the aggregate of basic conceptions underlying not only different, but even alternative and contradictory forms of propositional knowledge, irrespective of whether these forms are deemed right or wrong" (Marton, 1981, p. 197). In this, phenomenography adopts what Kvale (1995, p. 65) terms an "affirmative" postmodernist stance that decenters knowledge by rejecting the notion of a universal truth and accepting instead the possibility and value of specific local, personal, and community forms of truth (Ernest, 1997; Kvale, 1995).

True to qualitative research, the validity of the *outcome space* as a defensible representation of the phenomenon in question lies not in “some final product control or verification; verification is built into the research process with continual checks of the credibility, plausibility and trustworthiness of the findings” (Kvale, 1995, p. 7). In the present research context, where there is not access to a co-researcher to dialogically check the reliability of the findings, the onus falls to the researcher to clearly communicate the interpretive steps taken, supplementing these with illustrative examples. Indeed, “in a context where the concept of multiple interpretations of the same data has been legitimated, a strong emphasis must be placed on a researcher’s ability to argue persuasively for the interpretation that they have proposed” (Akerlind, 2002, p. 13).

In qualitative interviews, it is often the case that researchers check their findings with participants in order to ensure accurate interpretation. Given that I am not conducting interviews, this is not a viable option for checking validity but neither is it a drawback. Indeed, it is *not* normal practice for phenomenographers to check their categorizations with participants because interpretations are made on the collective—a holistic group, rather than on the basis of individuals in series. Without a sense of the group as a whole, interpretations on individual elements cannot be fully understood (Akerlind, 2002).

That said, phenomenographic findings should “be regarded as appropriate by the relevant research community” and they should hold up when checked against other samples from the target population (Akerlind, 2002, p. 13). In the present case, this means that the *outcome space* of ways of experiencing science should accommodate results of relevant studies located outside the *Public Understanding of Science* journal.

Method

Research Question

The present phenomenographic study begins a conceptual mapping of the phenomenon of science as experienced by and represented within various publics—mostly those of prominent western "Enlightenment" influence. Admissible data derives from cultures where science figures significantly enough in public consciousness to have motivated a research study of its presence. Such studies cluster in North America, Europe, Australia, and New Zealand. Recall that phenomenographic research makes no claim to a representative mapping of experiences of a phenomenon. Furthermore, a critical assumption about science underpins the rhetoric of its public understanding—that, unless otherwise stated, the term science typically invokes the construct whose lineage derives through the Royal Society of London for the Improvement of Natural Knowledge founded in 1660. It is to this science that Lewenstein refers when introducing the *Public Understanding of Science* journal's tenth anniversary issue. "Science is one of the key players in globalization, and the nature of public engagement with scientific knowledge and science-based technologies and industries has and will continue to shape public reactions to globalizing forces" (2002, p. 2). Accordingly, the studies available about science are, in practice, either directly about western science or, where alternative localized science constructs fall under scrutiny, the researchers consider these as against western versions. Publics and cultures untouched and unaware of this hegemonic science are both rare and rarely considered, if at all, in the literature about public understanding of science. Thus, a natural limitation exists in the data source and, in turn, this limitation restricts the present study to those publics holding various understandings about this dominant science of global influence and awareness.

The questions posed of these publics essentially fall into two classes. Owing to the object-subject relationship of experience, two complementary question sets must simultaneously focus attention on two corresponding faces of variation. The first asks about the object of science, "What are the different ways of experiencing science in and across various cultures?" The second concerns itself with subjective experience, asking, "Within a particular experience of science, what structural and referential aspects characterize awareness of that experience?

Locating an Appropriate Data Source

In selecting an appropriate body of studies to analyze, I looked to scholarly work that either explicitly addressed personally expressed experiences of science (or some element of science) by a particular public or that analyzed social representations of science (or some element of science) evinced in public artifacts—these artifacts mediating and presenting science overtly or covertly for reflexive public consumption. In sum, the data source needed to consider experiences about the nature of science's knowledge, its processes, or its players and these experiences could either be drawn directly from individuals or indirectly through social representations of/about science.

Descriptive study of experiences of science is a relatively new phenomenon in research on science and the public. Indeed, long-prevailing paradigms about a deficit public have focused research attention on the *assessment* and *judgement* of understanding of science, both in terms of appropriate attitudes and sufficient literacy (including literacy of content, processes, and, most recently, nature). To be sure, the above sorts of studies do not suit the present interest.

In addition, a number of studies address public perceptions, not of science in particular, but of the interplay between science, technology, and their socially- and culturally-embedded material and knowledge products. In this realm of social representations about science, two kinds of approaches speak to the reflexive public experience of science. Loosely put, one approach considers how science's products shed light on science's perceived character, while the other, considers how already-formed awarenesses of science's nature shed light on the character of its products. In the first instance, a researcher looks at the social representation of some particular product of science; for example, a knowledge product, say, the theory of evolution as mediated in a high school science text. The notions of theory, evolution, and science appearing in the text and further mediated in the classroom will shape a particular experience of science that may prove untenable in, for example, instances of frontier science. On the other hand, research could question how generalized notions about science affect the public uptake of particular science products. For example, an investigator might ask participants to comment upon their willingness to reach for synthetic versus "natural" medicinal remedies in terms of their levels of trust in science. Both types of studies speak to the experience of science in public and are therefore permissible candidates for consideration in the present research endeavour.

Sourcing relevant studies: "Public Understanding of Science" journal.

An initial search of scholarly writings on the public experience of science and the social representations of and about science resulted in a smattering of relevant studies for each of a variety of interchangeable (from a phenomenographic perspective[31]) search categories. The *Public Understanding of Science* journal remained consistently over-represented among the useful studies in all categories. Moreover, a follow-up of references from the literature review, invariably led to and from the *Public Understanding of Science* journal. Every category of researcher implicated in the nature of science had representative works in this journal—that is, the journal effected an exemplary multi-view on issues surrounding science as understood in culture and by various publics.

In the tenth anniversary issue, then editor, Bruce Lewenstein (January 2002) described the journal's intent.

> Unlike other publications devoted to increasing public understanding (whatever that might mean) or to providing comment on public interactions with science, we are fundamentally a scholarly journal, committed to publishing research

[31] Recall from page 121, that Marton (1994) emphasizes the interchangeable nature, in phenomenography, of the words experience, perceive, apprehend, understand, and conceptualize, etc. He does not deny differences in the meaning of these terms, but rather points out that the limited number of ways a certain phenomenon appears to us can be found and described in the phenomenographic sense, regardless of "whether, for instance, they are embedded in immediate experience of the phenomenon or in reflected thought about the same phenomenon,… [—that is, independently] of the differences between experience, perception, apprehension, understanding, conceptualization etc." (Marton, 1994, p. 4426).

based material that will enhance communal knowledge about the nature of public interaction with science. (p. 1)

Sage Publications described it as “the only journal to cover all aspects of the interrelationships between science (including technology and medicine) and the public” (Sage, 2005). A truly international effort, renowned researchers—spanning diverse perspectives and paradigms across the Americas, Europe, and Australia—people the editorial board. Included are feminist, Sandra Harding; quantitative analyst of science literacy, Jon Miller; sociologist of science, Steven Epstein; philosopher and anthropologist specializing in science, Bruno Latour; and science and technology studies professor, Stephen Hilgartner; to name a few. In 2005, Thomson Scientific assigned the journal an impact factor of 0.913, ranking it 13/42 in Communication and 3/29 in History and Philosophy of Science (Social Science). The journal has been and remains “a place where the conversation among… [deficit, contextual, and lay knowledge] models can take place, and where empirically-based scholarly work… [is] welcomed regardless of philosophical perspective” (Lewenstein, 2002, p. 1). Its contents span a wide range of topics and do not shy away from such controversial topics as the “science wars.” Its publics have included people “Russia, China, Australia, India, the Czech and Slovak Republics, Portugal, and Japan, as well as the wealthy countries of western Europe and North America” (p. 2).

Global in perspective and explicitly inclusive of multiple and often conflicting views, this journal is the premier venue with the mother lode of best studies examining the nature of science as experienced. In effect, the editorial board sifts through potential candidates to afford a multifarious sampling of studies best-suited to shed light on the experience of science in multiple and varied publics. Studies falling outside the journal's range would surely fall outside the range, in terms of quality and content, of those studies I seek.

A preliminary assessment substantiated the above claim and reassured that the journal offered sufficiently varied and representative sampling. From the first volume on January 1 of 1992 to the 14th on July 1 of 2005, there were 351 articles of which 57 address either personal experiences or social representations of science in a vein consistent with the present proposed study. The article foci broke down as follows: (Note that some articles could fall into more than one category).

Measures of literacy, attitudes, and perception: 72

Print media: 69

Images, metaphors, stories, and representations of science in public: 57

(Mis)trust, (mis)understanding, controversy, and/or risk: 36

Communication: 32

Science communication: 32

Science in culture and with regard to public policy: 32

Other: 28

Public uptake of science: 26

Fine arts & visual media: 22

Education: 16

Science museums, exhibits, and centers: 15

Ethics & juries: 13

Participatory science (i.e., public input to science): 13

Internet: 7

Market: 2

Limitations. For all of the above reasons, the studies from the *Public Understanding of Science* afforded the best cross-section of the literature on public experiences of the nature of science. Yet, practical constraints do limit any study. Owing to the newness of this area of research, there exist particular forums of science consumption that have not yet come under as much scholarly examination—either the studies do not exist or they exist in limited ways. Nonetheless, such a limitation in the availability of studies is more appropriately reframed as a wise delimitation. Without having first adequately charted the landscape of mainstream public perceptions, broaching the examination of exceptional cases would be premature. Further, in the spirit of phenomenographic research, fringe publics constitute interesting groups upon which to test and/or refine emergent typographies.

Accordingly, I can think of three underrepresented areas in the present study that might prove interesting venues for future research: the marketplace where science is used to sell, the Internet where information and misinformation run unchecked by formal authority, and specialized communities defined in part by their particular perspectives on science (e.g., fundamentalist religious groups, New Age groups, and primary consumers of naturopathic remedies).

In the marketplace,[32] conceptions of science as authoritative and trustworthy can expect to interplay with other factors—like perceived convenience of products,

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[32] Christopher Toumey addresses the use of science to sell products in his book *Conjuring Science* (1996). In her book, *Selling Science,* Dorothy Nelkin (1995) treats

immediate and long-term quality of life in using products, ethical leanings, and altruistic beliefs—in influencing certain consumer choices. This is especially true where advertisers invoke social representations of science to promote products like hybrid vehicles, organic produce, "natural" or "pure" food, low cholesterol food items, locally grown produce, less-packaged goods, and healing devices and remedies.

Likewise, the Internet affords an interesting future focus for study—its import increasing almost day-to-day. In ways that matter the Internet changes the dissemination and negotiation of social representations. For example, it shortens the mediating distance between producer and audience while broadening its accessibility from multiple sender-receivers to multiple receiver-senders. It introduces crucial versatility in accessible information, communicative lag time (unrestricted and uninterrupted time in both producing and responding to messages), 24-hour, at-home accessibility, and participant anonymity. Further, as with any medium, the Internet's unique qualities necessarily filter information according to the restrictions of the medium and of those receivers having variable access to it (Hemetsberger, 2002).

Finally, there are sub-genres of images that proliferate within specialized communities. For example, the images of western science presented in literature, television, film, and even music emanating from and targeting select audiences (e.g.,

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science as the product for sale. Leah Lievrouw (1992) tracks the movement of science ideas about lipid metabolism through successive iterations communicative loops of scientific conceptualization, then documentation, and finally popularization of this research. Through this example, where "cholesterol," "HDL," and "LDL," and related terms ultimately gain entry into lay vocabularies, she illustrates how the processes of big science effectively manoeuvre science products into public places by first objectifying science concepts and then anchoring them, through concrete associations, into the everyday lives of people.

fundamentalist religious groups, New Age followers, and primary consumers of naturopathic remedies) will likely differ significantly from those circulating in the more generalized public. If we are serious about recognizing a heterogeneous public we would be remiss in never attending to images concentrated with/in its subcultures.

Data Collection

As a first step in data collection, and with an eye to a subsequent full-blown phenomenographic analysis, I identified those studies from the *Public Understanding of Science* journal that fit either of two possible criteria: (a) They qualitatively described people's conceptions about science in general or in particular (such as in the contexts of nanotechnology, genetically modified organisms, fluoridation of water, or global warming); or (b) They qualitatively described cultural artifacts of science that themselves constituted social representations of its meaning to people (for example, science as represented in visual or performing arts, as communicated through the media, or as otherwise written about in materials intended for public consumption). As previously described (see page 145), a preliminary examination located 40 to 60 such studies.

Simon Locke's examination of ambivalence in representations of science and technology in super-hero comics (2005) counted among the many suitable candidates. Offering a broad-spectrum view of science in an intriguing and relevant context, the study was sufficiently typical of the types of studies available, broad-sweeping enough to begin a mapping, and amply descriptive for the kind of experiential detail needed to position such a preliminary mapping. A recent project, Locke's work satisfied the criteria for inclusion in the present work; that is, it focused on the experience of science as mediated through an artifact prevalent across much of popular Western cultures. Super-hero comics carry pop culture discourses about science to multiple publics. They "deal with questions about the social and cultural meaning of science that are constituted out of the same basic stuff as academic concerns" (Locke, p. 26). Indeed, super-hero comics are part of the stock of cultural products familial to this paper's audience. Moreover, Locke's literature review and analysis benefits from a growing body of discourse about the depiction of science in and through various public media—in particular super-hero comics. Thus, Locke's work served the present illustrative purpose well and constituted as apt as any starting point for embarking upon the exploration of science as publicly experienced.

As with other forms of qualitative, descriptive research, the phenomenographic investigator strives to bracket out personal perspective that (s)he might properly attend to the research subject (Ashworth & Lucas, 2000)—in this case, Locke's voiced observations. That said, the impossibility of truly bracketing oneself out, calls for mitigating strategies, usually in the form of laying out personal perspective as potential source of interpreter bias. To this end, two reflective activities proved useful. Previous saved editions of this thesis charted the three-year research journey through the public understanding of science literature. Shifts in personal perspective and understanding about the intersection of public and science provided a comprehensive narrative of my research experience and a first explication of researcher background. In a second effort to counterbalance the inevitability of the researcher self in the research, I turned the phenomenographic questions about science toward my own awareness. The process of self-consideration in terms of the structural and referential aspects of science provided a second backdrop against which to consider the present findings. Thus, this phenomenographic method appropriately began with a reflective turn for the purpose of outlaying the details of this author's journey with, and experience of, science.

In phenomenographic analysis, the process of data extraction emerges out of an iterative and phenomenographic consideration of the parts and the whole concurrently. Constant comparison calls for the consideration of the whole in terms of its parts and the parts in terms of the whole—a process meant to press for holistic perspective and understanding (Marton, 1986). There is no coding methodology that suffices to extract meaning and intent (Åkerlind, 2002). Instead, coherence of meaning between parts and whole become the basis for interpretation. In addition, the researcher, taking a phenomenographic lens to awareness, examines both the author's perspective (where evident), the perspectives given through the author's findings, and, if accessible, the interplay of the two. Key questions about awareness drive the data collection and its descriptive analysis (Åkerlind, 2002; Ashworth & Lucas, 2000; & Neuman, 1997).

The following descriptions outline how the phenomenographic model of experience directed three major iterations of data collection and descriptive analysis.

First iteration: Whole article.

The first iteration began with a preliminary reading of the whole article to set the contexts of the data source, the study's method of data collection, the author's findings, and, if evident, the author's position on the nature of science. The explicit goal of this initial reading was to immerse myself in the author's writing and to do so while highlighting key passages. This is the only point where the article was not considered in terms of the phenomenographic research questions. Thus, the initial stage of data gathering began with a self-introduction to the work that was, as much as possible, unfettered by the phenomenographic interpretive mode and therefore, as true as possible, to the author's intent. Launching directly into a phenomenographic analysis would have pre-empted fair consideration of the piece as it stood.

After grappling and coming to grips with the substance of the article on its author's terms, I re-read the now-highlighted piece considering both the key points and the general message in light of the phenomenographic research questions. In keeping with the research methodology, questions designed to target the nature of awareness of science had emerged from a clear formulation of the phenomenographic inquiry task. These questions were as follows:

1. What are the author's implicit and explicit positions on the nature of science? Are they consistent?

2. Where does the author look? That is, which public(s), cultures, and representations (e.g.: at symbols, multi-media, text, art) constitute the author's data source. Is that data primary or secondary?

3. How, if at all, does the author attend to the first face of variation; that is, the variation on the nature of science as objectively experienced across perspectives? [For ease of distinction, call this "inter-awareness" variation.]

4. How, if at all, does the author attend to the second face of variation; that is, variation in the nature of awareness within a particular subjective experience of science? [For ease of distinction, call this "intra-awareness" variation.]

5. If the findings speak to intra-awareness variation; then, how is that awareness structured? That is, within particular perspectives, what is admitted as science, what is deemed non-science, and how is the distinction made? Where are the boundaries—the edges—of science within particular perspectives and how clearly are they explicated? In what contexts and according to which variations of objective experience do boundaries differ? Are they mutable? If so, in what ways?

6. How is science value-laden? Within a given perspective, what meanings are ascribed to science and to non-science? What are the referential aspects of awareness that hold science together and distinguish it from non-science? What values and circumstances lend variable and particular meanings to science?

Second iteration: Section by section and, within each section, paragraph by paragraph.

Next I attended to one paragraph at a time in each section, posing the same questions and highlighting: (a) elements that captured the essence of the paragraph and held the thread of the author's ideas, and (b) descriptions and details that featured the answers to the sorts of questions posed to the entire piece (see above). Rereading the highlighted portions of a section, I created descriptive notes to capture that which was highlighted. Finally, I highlighted key portions of the descriptive notes and jotted analytical points alongside the highlighted notes.

Third iteration: Whole article from summarized notes.

Finally I re-visited the summarized notes—cross-referencing, if need be, with the original article—gathered summative observations, and formulated a word document that summarized findings and supportive evidence.

Data Analysis

With the data thus extracted from multiple studies, the landscape of public perceptions about the nature of science begins to take shape in the form of a two-dimensional mapping corresponding to the two faces of variation. Studies may inform the first, the second, or both faces of variation. From studies of the social representations of science—as examined, for example, through its cultural artifacts—I expect greater light shed on the range of experiences; that is, on the first face of variation. Qualitative studies of personal accounts of the experience of science are more likely to inform the nature of awareness within particular perspectives.

Recall that the first face of variation exists across an entire mapped phenomenon and consists of variations in awareness of that phenomenon, in this case, science. I have called this the inter-awareness variation. On the other hand, the second face of variation—or the intra-awareness variation—centers on the structural and relational natures of awareness within particular ways of experiencing. Thus, the phenomenographic analysis identifies and represents the first face of variation in the breadth of categories of experience of science of the *outcome space* and the second face of variation in the subjective experiences of awareness of science within each category.

Descriptions of the second face of variation should include both the structural aspects of awareness of science—what counts and doesn't count in an categorical theme of science—and the relational aspects of science. Within any particular category of experience, the relational aspects hold the category together in its internal horizon while rendering it sufficiently distinguishable from its external horizon. The internal horizon of a particular category of experience includes all the different possible appearances of science that constitute that particular understanding of science.

Recall the two components of the external horizon: the thematic fields and the margins. Margins include those things unrelated to the theme or phenomenon in question, in this case, science. They are vaguely experienced in awareness. The margins comprise those things unrelated to the theme except by their coexistence in space and time. A particular thematic field of science surrounds a category of experience of science and relates to that category by dint of relevance. It is the backdrop against which a notion of science is experienced and to which that notion of science belongs. The relevance between a theme and its thematic field is sharpest at borders of articulations and fades with distance into the thematic field. The thematic field is not finite. Accordingly, though it diminishes in relevance as it becomes further removed from science, it continues to occupy the same world of experience. That is, the thematic field of any phenomenon must include the total experience of the world within which the phenomenon exists.

In conducting the phenomenographic analysis, one asks: What specific elements cluster at the center of the theme of science? How do component parts and various perceptions cohere? In short, what is the nature of science's internal horizon? Likewise, the researcher considers the nature of science's external horizon, asking what thematic fields compose the immediate external horizon and how clear and consistent is the demarcation between that which is considered science and that which is not? Finally, what elements compose the margins of science; that is, what things unrelated to science but coexist in space and time?

In the process of defining the subjectively experienced structure of science (and, by contrast, of non-science) the phenomenographer pays particular attention to the related referential aspects of awareness—questions of meaning and value. What affects associate with and contribute to particular structures? For example, if the facts of science, as mediated by school texts, sit somewhere at the centre of science's structure, then with what meaning do these imbue science? Is science presented as certain and demystifying? If so, how does such representation impact the structure of science as against spirituality, for example? Conversely, if science is experienced as a means to magically split atoms and convert matter to energy, then does its business confirm the existence of the mystical and make probable all that is incomprehensible and unfathomable?

Were I to continue with a full blown phenomenographic research piece (and not a single exemplar in the form of an illustrative case study), I would begin with those studies promising the most comprehensive data and develop, through a process of sorting and resorting, a generalized picture of prevalent perceptions, these iteratively solidified into categories of descriptions about ways of experiencing science. In the unfolding, and according to the phenomenographic premise, the categories should become increasingly well defined and located within an emerging structure of science. Each subsequent study would inform the existing structure, either solidifying it or moving it in adaptive ways to incorporate the new data. The process would continue until a satisfactorily stable and meaningful structure emerged to express the multiple conceptions of science as both objectively existent and subjectively experienced.

Research Outcomes

In phenomenographic analysis, first and second faces of variation increasingly inform and refine each other yielding an emergent model that depicts the phenomenon as experienced in the collective awareness. Phenomenographic maps take many visual forms including charts, Venn diagrams, and 3-dimensional images. The researcher’s understanding of the *outcome space* and the desire for elegance in clear communication guide the form of the final model.

CHAPTER 4. PHENOMENOGRAPHIC CASE STUDY

Mapping the Researcher Experiential Lens

Recognizing both the importance and difficulty—if not impossibility—of staying close to qualitative data without pre-maturely conceptualizing it, I map my own thinking as an "experiencer" of science and learner-researcher about its nature(s). I begin by explicating a four-year research journey into the nature of science. Remnants of that journey lie between the lines of the literature review—itself the evolutionary result of successive revisions in writing and thought.

A Biography of the Research Journey

At a first layer of research, self-described skeptics and debunkers of pseudoscience joined ranks with researchers bent on measuring public scientific literacy on science's terms. Historical accounts of trends in science education confirmed the challenge and ineffectuality of trying to educate a sufficiently science-literate public. Philosophical writings detailing scientists' perspectives fell short of addressing the problem. Unaware of any other way of experiencing science in society, the literature reinforced a growing sense of pointlessness in trying to change something that clearly refused to be changed. I had begun as self-described seeker of truth and was now reconsidering the notions of truth and reality as singular entities devoid of context and perspective.

In a second layer of research, I encountered the Science Wars, Kuhn's *Nature of Scientific Revolutions*, Berger and Luckman's *Social Construction of Reality*, John Ralston Saul's *Voltaire's Bastards* and *On Equilibrium*, Sandra Harding's *Whose*

Science? Whose Knowledge?, and Fortun and Bernstein's *Muddling Through.* These authors challenged old ways of thinking, validated a growing sense of something amiss, and nurtured new perspectives about the experience and nature of science. Phenomenographic researcher, Ingrid Prosser, describes learning as "a question of perceiving, conceptualizing, experiencing, or understanding something in a different way from previously" (p. 84, 1996). I was learning. In the course of reconsidering and recontextualizing past experiences of science, I *re*membered early school years of disaffection with a singular scientific method and recipe-like laboratory investigations. I wondered about atomistic ways of perceiving and asked, "If science had been governed differently—had asked different questions—Would we have still missed the forest for the trees? And, would I have felt more at home in science?

I reconsidered science and saw it as socially and culturally implicated. Scientific facts and theories became particular forms of knowledge emerging from and dictated by the types of questions asked and the ways of looking at answers. Increasingly, social, economic, political, and/or cultural forces emerged as key forces dictating the formulation of both inquiry questions and the particular reading of answers.

Having wandered through a quagmire of debate about the nature and role of science in society, the challenge of formulating a clear forward-moving question to focus this thesis proposal had grown disproportionately large and altogether overwhelming. In retrospect, and from a phenomenographic perspective on experience, I faced the difficulty of holding simultaneously conflicting views on the "ought" and "is" of science in the world. I would need to reconstruct my experience of the problem. Research at the intersection of science and public—in the so-called "public understanding of science" realm—attended to the position and mediation of science in culture. Here was the help I sought. Science communications researchers addressed one and two way exchanges of information and perspective between science and public. Sociologists considered the roles of trust and belief in science as an epistemic authority. And, anthropologists traced the historic interplay of science and culture. In these writings, neither science nor non-science held constant privilege. The works were less about who was right and more about exploring a sometimes muddled middle ground that admitted multiple valid conceptions on the experience of science's nature. These readings coupled with Moscovici's writing (1988) on social representations enabled the fermentation of a current research project—to pull from the work on the public understanding of science a typography of the public experiences of science. Still, no appropriate method existed in my realm of experience.

A final wave of research, this time into qualitative methodologies, led to social cartography and, within it, phenomenography. In this methodology lay a means to honour and give simultaneous balanced voice to multiple views of a phenomenon—in this case science. Before proceeding with any phenomenographic analysis of other works on the public understanding of science, it is prudent for me, the researcher, to turn the phenomenographic lens of understanding about science onto myself and to explicitly lay out the results of that undertaking in order to map my "biases" and preconceptions and account for them in my processes of inquiry.

Preliminary Phenomenographic Map: Researcher's Experience of Science

First Face Of Variation

I recognize three personal categories of experience of science: (a) science as empirical inquiry, (b) science as institution, and (c) science as servant-producer (see Figure 1).

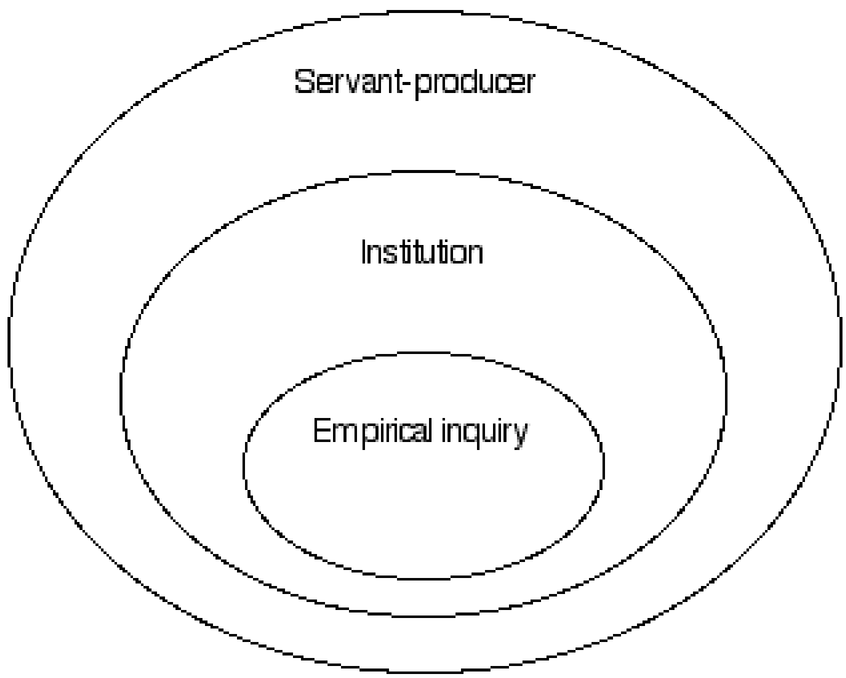

Figure 1. A model of awareness of science showing nested categories of experience.

These perspectives are embedded one in the other. Yet, in much the same way that a person sees either the duck or the rabbit in the ambiguous image of Figure 2, it is difficult to hold more than one category in awareness at a time. Thus, for example, when *empirical inquiry* is in focus, the *institution* and *servant-producer* views recede into the *thematic field*.

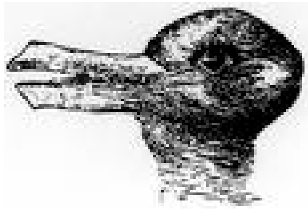

Figure 2. Duck-rabbit illusion.

Second Face Of Variation

Within each category of experience of science, awareness changes. The *second face of variation* describes the structures and meanings of awareness of science within each category of the *outcome space*.

Science as empirical inquiry: Structural and relational aspects. Stable, at the core, and characterizing the internal horizon of this category of experience of science, reside the methods and processes of empiricism—namely: systematic and careful observation, documentation, and communication of findings. Attempts to minimize, or at least make explicit, individual subjectivities also exist at the centre of scientific inquiry. Practices associated with this goal include open disclosure of the researcher-self and adherence to rigorous standards for measurement, analysis, and the dissemination of results. Science proceeds in spiral-like process from observation and inductive reasoning about that which is observed, to theory formulation and deductive reasoning in theory testing and the generation of falsifiable hypotheses. The notions of experimental design, statistical analysis (meant to isolate or otherwise disentangle variables, assess causation or correlation, and measure effect size), and peer review are key complementary and necessary processes in the sense-making capacity of science.

If methods and procedures are science's structure, then its meaning lies in its ability to observe our world and examine categorizations for patterns and relationships, document where and how these exist, and use such patterns to explain past events while accurately predicting the consequences of future ones. As Francis Bacon imagined, science as *empirical inquiry* represents a refinement of the human ability to learn from nature. Fractal-like, this life-planet yields different truths at different depths. And, as with fractals—though there be self-similarity of parts to whole—in zooming in, we risk missing the scaled implications of a greater sum, and in zooming out we risk either dismissing micro-complexities or losing ourselves in efforts to grasp a macro-view that simultaneously entails equally complex micro-views. In short, while science is *empirical inquiry* and a powerful means of making sense of the world, it nonetheless carries inevitable fallibilities of perception. Both tacit and explicit choices made in selective attention constitute unavoidable biases in science.

Thus, as *empirical inquiry* and satisfier-of-curiosity, science cannot outwit the inevitable interplay of subject and object. Past experiences afford the pool of possible resources brought to inquiry. They simultaneously enable and disable: (a) how one perceives, (b) the vantage point one chooses to perceive from, and (c) the depth of focus one takes in perceiving. Together these biases of awareness interact with the thing perceived to subsequently shape patterns and understandings "discovered" and presented in the name of science.

Moving outside the internal horizon of science as *empirical inquiry,* one enters a related, but qualitatively different, external horizon. At the edge of science, begins a contrasting world of hunches, intuition, and belief. Let me be clear that I do not present these other informants to knowing as ill-considered or inadequate. Rather, they are uncharacteristic of the experience of science as *empirical inquiry.* Neither should we deny the invaluable roles of intuition, creativity, belief, imagination, nor altruism as motivations that direct and inspire the questions asked of and by science. Indeed, these constitute important individual and cultural human factors that situate and contextualized science in a larger world.

Still, just outside science, but often passing as science, are nebulous places where the signs, symbols, and language of science exist in manner stripped of the rigour of scientific inquiry. For example, at the edge of science we find such unscientific activities as: (a) unsystematic "experiments" in everyday life; (b) algorithmic laboratory "investigations", often with results made to fit expected outcomes; and (c) after-the-fact stories, presented as tightly woven theories (and selectively supported in anecdotal accounts) to both explain perplexing phenomena and promote certain behaviours and beliefs. When such keystone concepts as theory and evidence take on non-scientific meaning, the edges of science as *empirical inquiry* become blurred. It is at this edge that my experience of science as *empirical inquiry* runs into difficulty in the public arena.

Science as institution: Structural and relational aspects. In the theme of science as *institution*, the social structure, history, and culture of science come to the fore and the relational and affective aspects of science change significantly. Science as *empirical inquiry* is but one element of science as *institution.* Strangely, whereas I identify with, and value, science as *empirical inquiry*, as woman, it is easy to feel displaced from and mistrust science as *institution*. The Royal Society of England and a privileged collective of males occupy the center and structural foundation of this decidedly Western science. It permeates much of my rudimentary experiences of science in action in education, big business, and government. High school and university physics, chemistry, and biology instructors were predominantly male and inquiry in school settings continued a tradition of myopic and linear views. Science the *institution* felt and often feels as inaccessible and single-minded as most other institutions of male prevalence, power, and politics and I alternately define myself as better than that and not good enough.

Interestingly, this second category of science as *institution* resists entry to the social sciences. Likewise, the ecological sciences are only questionable members. Science as *institution* is ensconced in Western culture. It conveniently serves the market place and hidden agendas with ingenious but highly situated quick fixes. This is an unambiguous science that fascinates and mesmerizes without challenging the status quo. Accordingly, it exhibits tremendous institutional inertia.

The internal horizon of science as *institution* contrasts against an external horizon of other, less legitimate, sciences that engage a more complex world. Indeed, these renegade sciences, the new (and non-gendered) kids on the block, are simultaneously engaged in redefining the old boys' club while sustaining membership in a new club of "less pure," softer, and more transdisciplinary inquiry. Daring to explore muddled and complex systems involved in human behaviour and invoked at the interplay of life and non-life in the biosphere, these newest contenders employ rigorous processes of a different type. Still, their qualitative techniques and findings—contentious against clear-cut quantitative standards set by "harder," more atomistic approaches—relegate them to a realm just outside the bounds of science as *institution.* And, though this category of experience may be shifting in some academic circles, it persists, alive and well, in most everyday places of the Western world.

Science as servant-producer: Structural and relational aspects. The third category of experience, science as *servant-producer*, encompasses science as *institution* and, within it, science as *empirical inquiry*. Here toils the servant-scientist, employed by society to expand human abilities and potentialities through technology. Central to this theme, is the curious, inventive scientist absorbed in *his* work. Motivated by some combination of societal need and personal ingenuity, he puzzles over observed phenomena and collaborates with other scientists to both create explanatory models and generate technological tools.

Science as *servant-producer* maintains an aura of privilege in terms of the respectability and reliability of scientific findings, but it is not privileged in terms of its own agency. In this view, science does not formulate its own questions. Instead, various other societal institutions engage science to create technologies for enhancing: (a) human perception—via models and tools that enable greater and varied discernment of similarity and difference and (b) human agency—via technologies that press the natural world to succumb to human will. The first enhancement satisfies our curiosity and builds certain knowledge while the second affords power and the illusion of control over nature. In the first, nature appears to teaches. In the second, nature is subdued.

Occupying the internal horizon of science as *servant-producer* are those scientists whose livelihoods depend upon meeting the needs of their sponsors. Put differently, the external horizon of science dictates to science as *servant-producer*. Accordingly, external forces—be they economic, political, or social—ultimately determine which questions will be funded and which lines of inquiry, being less popular, will not. In this conception, science is subservient to a larger society and to motives other than its own. Such a science is, in effect, society's tool, wielded to society's benefit or detriment as the particular institution dictating the questions sees fit.

At the same time, science as *servant-producer* is prestigious by virtue of its privileged empirical methods—these methods and the purity of science nested within this theme. Privilege makes of science the ideal scapegoat for any misuse of its products. As *servant-producer*, science findings can be silenced or publicized at the will and motive of the patrons of scientific research. In the perception of *science as servant-producer*, scientists and science are accountable for both the use and misuse of technologies created. The public image of science suffers both praise and derision depending upon whether technologies benefit or prove problematic. As ingenious creators of tools, scientists contribute to and attempt to solve ever more complex problems. At the same time, as public servants they are held under suspicion if their findings press for unsolicited societal change. In short, in this broadest view of science, scientists can be dictated to, but they cannot dictate.

Data Source for an Illustrative Phenomenographic Case Study

As described in chapter 3, the body of studies selected for phenomenographic analysis should span the breadth of experiences about science—its products, processes, and expert workers—as both reported by particular publics and as evidenced in particular instances of public representation. In the case of public representations, the sought after studies would qualitatively describe cultural artifacts of science that themselves constitute social representations of its meaning to people. Simon Locke's (January, 2005) rhetorical analysis of super-hero comics is one such study and a suitable candidate upon which to conduct the present illustrative phenomenographic case study of *Public Understanding Of Science*.

I present the data collection and rudimentary analysis in terms of the phenomenographic questions asked of Locke's research (see Chap 3, pp. 151 – 152). Recall that the first phase entailed holistic readings of the study—first, and in order to stay close to the author's intentions, without regard to the phenomenographic questions and, thereafter, taking the phenomenographic questions to these intentions. In the second iteration, paragraph-by-paragraph examination served to realign, thicken, and sharpen initial impressions with explicit details noted from the document itself. At the third and final phase of data extraction, whole and part were brought together to formulate comprehensive answers describing the awareness of science as uncovered through Locke's work.

Remember that this method of data extraction is not particular to phenomenography. Rather, the data analysis—that is, its interpretation according to the faces of variation and natures of awareness—is the characterizing feature of any phenomenographic methodology. Accordingly, this illustrative example focuses on the application of phenomenographic questions to the data as given by Locke's analysis of super hero comics.

As a final reminder, one should recognize that it is not possible to properly generate a final phenomenographic map in such an abbreviated manner as from a single study. The present effort entails but a blueprint for phenomenographic analysis. As such, it can only be a first step in mapping the nature of science as experienced. Were the research continued, analysis would repeat on subsequent studies, feasibly bring into view perspectives that support, refute, supplement, or entirely reconfigure the present offering.

A preliminary look at three other studies follows the analysis below. Though these studies appear to align and support the rudimentary map set forth here, one could equally expect data from subsequent analyses to turn our view in considerably different ways. The final mapping that arises out of a full-blown study may suit a coherent Euclidean representation or it may unfold into a conglomerate of experiences of science that when networked together constitute a complex system of shared understandings. In any case, the shape and composition of the sought-after final outcome remains, at this point, an unknown waiting its timely unfolding.

Data Collection

First Iteration: Precursory and Contextual Considerations

A preliminary reading directed this researcher's attention to key author points and perspectives. That is, in reading the article and highlighting key phrases, I acquired a descriptive general sense of the study. To minimize interpretive bias, I did not at this time consider the article in terms of the phenomenographic research questions. Only in subsequent readings of the highlighted article, was it appropriate to turn to the phenomenographic research questions for interpretive direction. In the process, excerpts, especially from highlighted points, became the citations that would appropriately support the present work.

Observations, thus drawn from the example of Locke's study, follow directly.

Locke's Position on the Nature of Science

What were the author's implicit and explicit positions on the nature of science? Were they consistent?

In this paper, Locke appears neither expressly concerned about any absolute nature of science, nor does he hint of any personally held, tacit, or preconceived notions about its nature. Rather, he looks to impressions about science in popular culture as indications of the "social and cultural meaning of science" (p. 26). The established model of science popularization—inadequate in Locke's estimation—sees science as active and monolithical in its impact. Against this so-called "canonical account" (p. 25) of the public as passive, Locke's analysis contributes "to the development of more informed and sophisticated understandings.... of the public uptake of science as active and 'multiplex'" (pp. 25-26).

Locke's Source of Data

Where did the author look? That is, which public(s), cultures, and representations (e.g.: at symbols, multi-media, text, art) constituted the author's data source. Was that data primary or secondary?

Locke provides a personal reading of fictional representations of science in artifacts of Anglo-American popular culture, namely super-hero comics. He begins from a premise that texts—in this case super-hero comics—are suasions and that the particular representations of science and technology located in such texts function as arguments whose constructions can be unpacked using the techniques of narrative analysis, metaphor and metonym, and semiology (p. 29). According to Locke, the representations of science in super-hero comics are especially valuable to the argument that in awareness of science "we all draw from the same rhetorical well" (p. 29). In his conception, super-hero comics—as popular and not high culture, as neither art nor literature, and as the most outlandish genre of fantasy—occupy a low social status and thus stand in stark contrast to academia. Yet, he finds that when representations are unpacked, superhero and academic discourses reflect the same complexities and ambivalences about science. In his accounting, and consistent with a phenomenographic perspective[33], this owes to a common cultural pool of understandings (p. 29).

First Face of Variation: First Considerations of Inter-awareness

How, if at all, did the author attend to the first face of variation; that is, variation on the nature of science as experienced across perspectives?

Locke begins by detailing experiences of science as given by various social theories about science. He dubs these perspectives the academic set. He then analyzes

[33] Recall the phenomenographic premise that there exist limited numbers of ways of experiencing any phenomenon and that these ways exist in varying degrees of representation throughout a culture and, in the case of science, perhaps even extending to that which is globally experienced.

images of science in super-hero comics and classifies these perspectives as the popular set. In his consideration, academic and popular accounts share similar enchantment/disenchantment themes about science—a commonality deemed supportive of his thesis that both accounts draw from the same “rhetorical well” (p. 29).

Locke’s recounting of academic perspectives on the public experience. From contemporary social theory Locke pulls two contrasting perspectives about the ordinary person’s experience of science. Max Weber’s thesis of ‘intellectualist rationalization’ forms the basis for science as disenchanting. In its potential to explain all things previously unexplainable, science demystifies (Locke, 2005, pp. 26-27). Conversely, science’s exclusivity and inaccessibility alienate ordinary folk. Accomplishments, forged in mysterious and distant places, appear as acts of “imponderable magic” (p. 27). In this way, science enchants.

In a variation on the latter perspective of enchantment, “the continuing presence of enchanted outlooks even within science—notably in positivism, [is] marked by ‘both an attitude of adulation toward technologic possibilities and an attempt at a comprehensive understanding of the human situation’” (Whitehead, 1974 in Locke, p. 27). This attitude finds expression in science fiction’s attempts to unify all ways of knowing—that is, in science fiction’s melding of magic, mysticism, spirituality, and science. Locke’s work moves toward “understanding how and in what ways science fictional scenarios may be made to seem plausible to their audiences.... the issue of plausibility [being] ... particularly pertinent to super-heroes” (p. 28). In as much as “more-or-less accurate” science can account for supernatural (i.e., magical, mystical, or spiritual) abilities, it is used accordingly. Indeed, in the science fiction of super-hero comics, plausibility motivates but also supersedes accuracy in rendering explanatory scientific narratives.

Locke closes his literature review by forwarding a thesis of science as malleable.

> Taken as a whole, then, science would appear not to be (just) one or the other, but rather a set of potentials and possibilities towards both [disenchantment and enchantment].... Thus the contrasting models of rationalization can be viewed as alternative visions of science that we should expect to find at work (working through and being worked out) in popular culture as much as in the academic world—as indeed we do in the comics.

Locke's reading of representations of the public experience of science in super-hero comics. In Locke's judgment, the disenchantment-enchantment formula does not capture the complexity of representations of science in super-hero comics (p. 42). He describes and analyzes three classes of representations of science in super-hero comics: processes, products, and expert workers. In terms of the present study, each representation became a viable candidate for a *category of experience* of science. Further, according to Locke, each representation acquires relational meaning via "the full range of characteristics that might be associated with disenchanted and enchanted images of science" (p. 42). Locke advances a relational aspect of awareness that is considerably more complex than the simple disenchantment-enchantment account.

The **processes** of science as represented in super-hero comics afford an experience of science as "something sacred and extra-ordinary, as more than human"

(p. 42). At the same time, they provide the means by which ordinary people can transcend everyday life to enter into or attain contact with a "cosmological order in which all ways of knowing and being are accorded their place" (p. 42). Similarly, the material and knowledge **products** of science can be taken as concurrently enchanting and disenchanting. Technology disenchants when it enables contact with "the sacred cosmological order, whether through using it to attain super-status, or to undertake a journey to an enchanted realm, or, as a *machina ex deus*[34] to bring a story to resolution" (p. 42). Conversely, technology enchants and dis-empowers humans in as much as it threatens the loss of humanity and confounds the boundaries of humans and machines. Finally, super-hero comics represent the **scientist** alternatively as savior-hero or mad villain—both employing techno-magic to intervene in the world. Either scientist "is just as likely to bring harm as... to be undone by factors beyond the capacities of science to control" (p. 42). In this representation science and "scientist are never simply one thing, but multiple, mixed, and moveable" (p. 42).

Second Face of Variation: Considering Intra-awareness

How, if at all, did the author attend to the second face of variation—that is, variation in the nature of awareness within a particular experience of science?

Addressing this, and further substantive questions about the structural[35] and relational[36] aspects of awareness, necessitated a detailed analysis as per the above

[34] Locke inverts the expression *deus ex machina* to *machina ex deus* to capture the notion of a technological innovation that magically, and in God-like fashion, brings resolution to a here-to-fore irresolvable situation.
[35] Structural aspects of awareness: If the findings spoke to intra-awareness variation; then, how was that awareness structured? That is, within particular perspectives, what was admitted as science, what was deemed non-science, and how was the

descriptions of second and third iterations in the data collection process (see pp. 152 - 153).

Second Iteration: Isolating Relevant Data

In the second phase of data collection, journal notes traced the article content paragraph-by-paragraph to create a log outlining discursive points in the context of present research questions. A scanned page of that log appears in Figure 3.

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distinction made? Where were the boundaries—the edges—of science within particular perspectives and how clearly were they explicated? In what contexts and according to which variations of objective experience did boundaries differ? Were they mutable—if so, in what ways?

[36] Relational aspects of awareness: How was science value-laden? Within a given perspective, what meanings were ascribed to science and to non-science? What were the referential aspects of awareness that held science together and distinguished it from non-science? What values and circumstances lent variable and particular meanings to science?

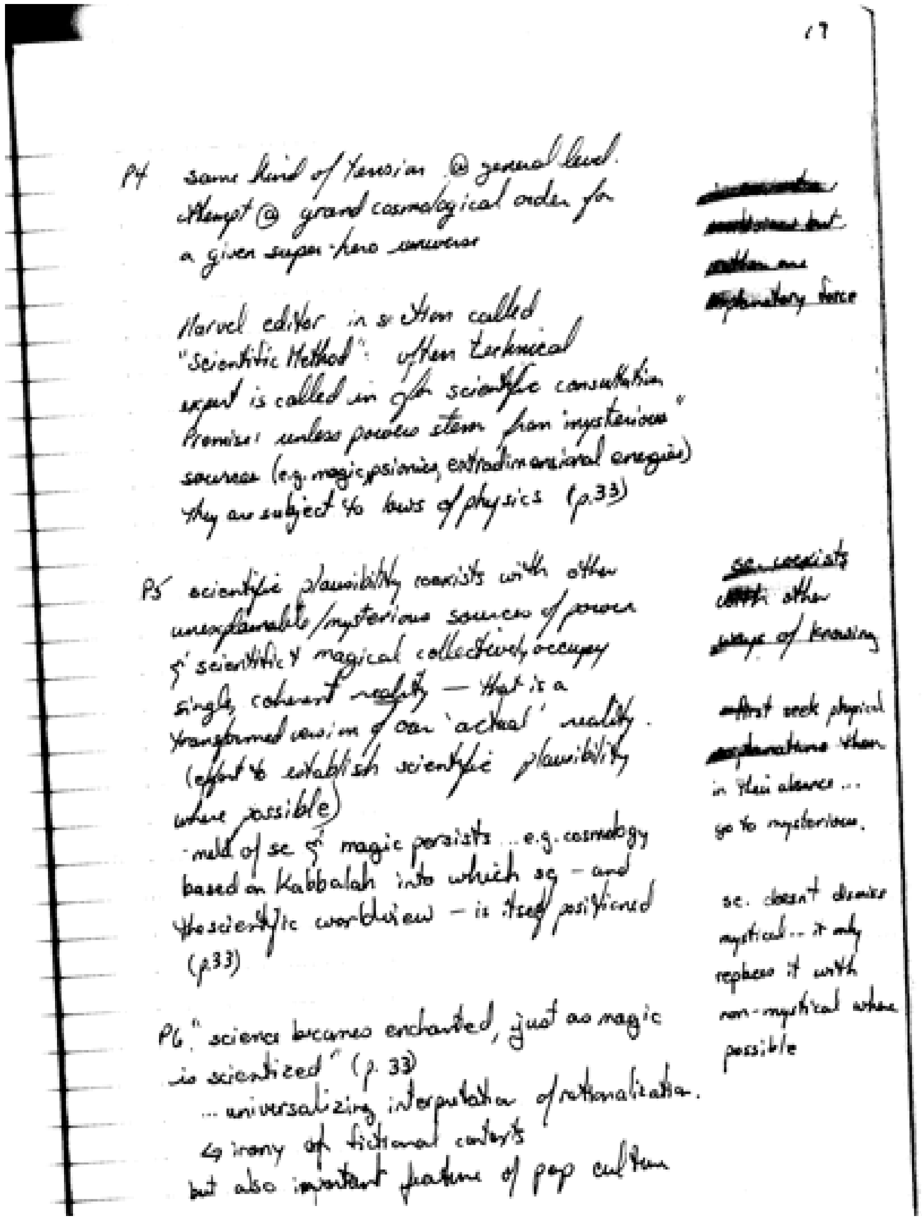

Figure 3. Page 19 of journal log.

Third Iteration: Whole Article Summative Notes

At a third level of data collection, a summative document itemized key descriptors according to the research questions. Article texts—extracted via the journal log—accompanied these descriptors to: (a) add clarity, (b) document findings, and (c) provide easy access for present and future cross-referencing.

For the present illustrative intent, I present the actual summative document in sections and preface these with interpretive notes. For ease of distinction, the original summative piece, as collected directly from Locke's study, sits in textbox inserts.

As shown below, a summative document begins with the study's complete citation. Next, italics draw attention to, and set apart, the relevant phenomenographic questions—these serving as main organizational headings. Under each heading, and in bold, appear the appropriate titles from the article proper.

Locke, S. (2005, January). Fantastically reasonable: Ambivalence in the representation of science and technology in super-hero comics. *Public Understanding of Science, 14,* 25-46.

What is the context of the study (the data source, author's rationale, and the study's method of data collection)?

(Section 1: Introduction)

⇒ According to Locke, popular science is more complex than academic accounts would have it.

- Purpose of the paper (as put forward by Locke):
  - To move toward
    - More informed and sophisticated accounts of popular science
    - A view of the public uptake of science as active & "multiplex"
  - To move away from
    - Established models of science popularization as a question of science as disenchanter or enchanter
    - Views of science as active and monolithic in its impact
    - Views of the public as passive or a best merely reactive
    - To examine fictional representations found in popular cultural media (e.g. super-hero comics) toward better knowledge of forms and features of popular science

Note that, in the first and second iterations, data collection followed the line of thought of Locke's research explications. Now, in this third iteration, the phenomenographic research questions take precedence over the author's sorting of ideas. Accordingly, I began with a document of italicized headings—the key phenomenographic questions. Thereafter I re-read journal notes, cross-referencing to the original article as needed, in search of sections where the work spoke to these questions. These "answers" were noted and referenced by section, page, and paragraph number as needed. Thus, in his introduction, Locke sets his research context. Then again, in Section 3, he further explains why super-hero comics are a likely source for learning about science in culture.

(Section 3: Super-hero comics, Introduction)

We can look to super-hero comics to learn about science in culture: In this paper, Locke assumes a premise of rhetorical analysis that texts—in this case super-hero comics—are suasions and that particular representations of science and technology located in such texts function as arguments whose constructions can be unpacked. It is in the unpacking (i.e., Locke's particular reading), through techniques of narrative analysis, metaphor and metonym, and semiology, that Locke finds ways of describing the experience of science (Section 3, ¶ 1 & 2).

According to Locke, the representations of science in super-hero comics are especially valuable to his argument that in "awarenesses" of science "we all draw from the same rhetorical well" (p. 29). In his conception as thrice-damned in society—that is, as popular and not high culture, as neither art nor literature, and as the most outlandish genre of fantasy—super-hero comics occupy a low social status and thus stand in stark contrast to academia. Yet, Locke finds that when representations are unpacked, super-hero and academic discourses reflect the same complexities and ambivalences about science. In his accounting, and consistent with phenomenography[1], this owes to a common cultural pool of understandings (Section 3, ¶ 3).

In Section 2, Locke considers academic views on the public meaning of science, and provides commentary on the enchantment-disenchantment themes that he considers prevalent in contemporary social theory discourse about science.

In this portion of the summative document, the words “how structured” and/or “what meaning” sometimes appear in square brackets—occasionally with explanatory notes. These words flag entries according to aspects of awareness. In keeping with previous methodological analyses (see Neuman, 2002), I use the word “how” to reference a structural aspect of awareness, and the word “what” to correspond to the referential aspects that assign meaning to that structure.

What is the author’s position on the nature of science or of the public understanding of science?

(Section 2: Disenchantment versus enchantment)

⇒ There is ambivalence about the nature of science [How structured] and the meanings ascribed it [What meanings] and these are associated with the “rise of science and the manner in which it is represented” (p. 28).

⇒ Science is a set of potentials and possibilities [How structured] toward both enchantment and disenchantment, depending on the particular argumentative purpose desired (Section 2, ¶ 4, p. 28 especially). [What meaning]

⇒ As potential explainer of all things, i.e., through “intellectual rationalization” and technological reductionism (the reduction of human and social being to one-dimensional machine-like measure) it can seem disenchanter of the world (Section 2, ¶ 1 & 4). [What meaning]

⇒ As object of positivist adulation, confident instrument of enlightenment, keeper of “profound mysteries surrounding the generation and maintenance of scientific knowledge” (p. 27), and distant unifier of all ways of knowing it becomes a “sacred” order for an enchanted world where paranormal phenomena “attain verisimilitude and scientific plausibility” as mystical states suited to a science context (Section 2, ¶ 2, 3, & 4). [What meaning]

Also in Section 2, it becomes evident that Locke assumes a parsing of science into three components: scientific processes, products of science, and science's expert workers.

First face of variation (inter-awareness): How is the structure—the overall map—of science assembled? How do categories of experience define and structure the outcome space?

(Section 2: Disenchantment versus enchantment)

⇒ To think of science means to include its

- processes (inquiry processes, its internal functioning as an institution, and its external relationships as a member of society),
- products (knowledge and technological), and
- expert workers (i.e. scientists).

⇒ Above is assumed throughout in the context of the author's writing: The author attends to science in terms of process, product, and expert workers in his treatment of the particular images of science represented in super-hero comics

In considering the second face of variation, and to maintain clarity with the phenomenographic terms of structure and awareness, this portion of the document begins with the two focusing questions of intra-awareness variation.

Second face of variation (intra-awareness): Within each particular category of experience, how is awareness structured and what referential aspects give relevance and meaning to science?

Structural and referential aspects of nature of awareness of science (How & what of science's assemblage)

1. **Structural:** How is the phenomenon or theme of science structured so as to differentiate science from non-science and to connect the elements that are science?
2. **Referential:** What referential aspects ascribe meaning to the experience and structure of science as perceived and apprehended?

Perspectives on the phenomenon of science inhering in super-hero comics as determined by the author's particular reading.

(Section 3: Super-hero comics, Sub-section: Science-magic constellation)

⇒ Science of the times, along with religious and political forces, read into super-hero comics.

- Biblical tones (p. 31):
  - good vs. evil
  - the mundane (Clark Kent) vs. the "sacred" (superman)
  - Superman's origins has parallels with Moses & sun-gods (¶ 4)
- Superman: working class tough guy image…
  - hero of industrial age
  - idealized image of masculinity (¶ 1)
- Echoing the popularity of science of eugenics, science legitimizes the special abilities of super-heroes (e.g. superman's strength is explained as analogous to the "super strength" of some insects) (¶ 3) [Meaning: Science can produce superhumans.]
- Linking theories of evolution with progress & advancement… superman's race evolved into more perfect specimens (¶ 2).

(Section 3: Super-hero comics, Sub-section: Continuity & origins)

⇒ Science is not a worldview but rather one of a number of explanatory forces (a first-line of explanation). [Structure: Science as *producer* of explanations]

Locke addresses intra-awareness variation primarily in Sections 4 and 5 of his article. Accordingly, the final portion of this summative document mirrors his chronological progression through the article. Collected descriptions, citations, and paraphrasing continue to gather and recapitulate Locke's reading of the experience of science evidenced in superhero comics. Page and paragraph marks refer directly to the article. Preliminary observations, set in square brackets, chart interpretive thoughts, and together with highlighted notes, flag the data for later analysis.

⇒ Science coexists with other ways of knowing. Science need not dismiss the mystical. It only replaces it with non-mystical where possible. (It's a "hole" filler in explaining the unexplainable… the magical… the mysterious.) [Structural: Science as *producer* of explanations]

- Super-heroes present enchanted images of S&T… constructed from and commentating on elements of the 'real' world… and in the process they change science (¶ 1).
- Super-hero comics construct an imaginary reality (p. 32) where sources of heroes' powers (i.e. science, magic, religion, myth,…) are configured as compatible within the same universe… though this constitutes a source of tension at a level of the particular (e.g. Thor co-exists with Iron Man) and the general (attempt at a grand cosmological order) (¶ 2 - 4).

⇒ Meld of science and magic (¶ 5). "Science becomes enchanted, just as magic is scientized" (p. 33, ¶ 6) [Structural: Scientific *processes* coexist with other ways of knowing. Meaning: Transfer of meaning from magic to science.]

- "Scientific plausibility coexists with other unexplainable/mysterious sources of power and scientific and magical collectively occupy a single, coherent reality" (¶ 5).
- Marvel's "Scientific Method": a technical expert offers scientific consultations on that which is physically possible. Premise behind multiple co-existing universes – Unless powers stem from 'mysterious' sources (e.g. magic, psionics, extraordinary energies), they are subject to the laws of physics (p. 33, ¶ 4).

(Section 4: Science & Magic in Marvel, Sub-section: Atom-age heroes)

⇒ "ambivalence about science as a source of tremendous power and of equally tremendous threat" (p. 33) [Meaning: *Products* of science can be fearsome. Altered people can be products of science.]

⇒ when science interferes with nature… "freaks of nature" result [What meaning]

- in post-atomic era (early 60s), super-hero powers are wrought by radiation
    - e.g. Incredible Hulk; X-men, Spider-man
    - note a darker tone (than earlier super-heroes like Superman) associated with these powers
        - Hulk: modern-day Jeckle & Hyde
        - X-men: outlaws rejected by the society they seek to protect
        - Spiderman: "With great power there must also come—great responsibility" (p. 34, ¶ 3). His personal struggles implicate science as "a focus of personal desire and a source of personal trouble—and, often, the means of resolution" (p. 34, ¶ 3).

(Section 4: Science & Magic in Marvel, Sub-section: Cosmic beings)

⇒ Cosmic beings in super-hero comics point to important ways "in which science is perceived and understood within popular culture and some of the peculiar tensions within this" (p. 35).

⇒ Science becomes the tool for connecting a mystical, magical, spiritual world with an everyday one. It provides the means for accessing the power of the magical and a means for interjecting the magical into the everyday. As such its presence is both distant and present. It is implicated as both neutral observer and active force. It promises a vision of hidden power—of both release and control. Its power to alter the natural everyday world makes it a force of which to be wary—something not to be trusted. [Structure & Meaning: Power is a fickle and untrustworthy *product* of science. Scientific *processes* humanize by rationalizing in mysterious magic-like ways.]

- Tensions between science knowing and ancient beliefs are played out in whole races of space gods and in specific characters who "themselves embody aspects of a modern scientized worldview" (p. 34, ¶ 2)
- Science serves to offer "reasoned" accounts of cosmic beings and entire pantheons of god-like beings, themselves drawn from traditional religions and mythological beliefs (p. 34, ¶ 1).
- Whereas traditional beliefs are typically held to express abstract principles in the form of oft-capricious mythological beings, science speaks of abstract principles in non-personal ways that link to disenchanting effect (¶ 2). Yet, when, in super-hero comics, the abstract notions of science are embodied in specific characters, science becomes humanized and humans become scientized. (E.g. Beyonder is the human-like embodiment of an alternate universe. Eternity is the sentient life-force of the universe.) (pp. 35 & 36, ¶ 2 - 4).
- Characters like Galactus (origins couched in "Big Bang") are both of science and not of science. They occur within science but transcend it. They are scientized and wholly other (¶ 3). "Galactus represents Marvel's take on science's creation myth, personifying and thereby investing it with something of the spirit of enchantment" (p. 35).
- The Watcher, garbed in philosopher-like Greco-Roman robes, is a member of an ancient alien race who "attained a level of cosmic transcendence through scientific and technological mastery" (p. 35, ¶ 4). Thus, in him, science is used to create that which is mystic and other-worldly. The Watcher represents the triumph and disaster of scientific intervention, the resolution of which is a state of passive, pure observations. [Meaning: Science creates that which is other worldly including scientists who then watch dispassionately the effects of science's processes and products.]

- The personalized forms of cosmic beings connect the sacred (mystic) and the profane (everyday) and science provides the explanatory force for that linkage (¶ 4). They "represent the vision of hidden power that science promises to release and control" (p. 36).
- Super-heroes stand in awe and wonder at this scientized cosmic order—themselves representing mediating conditions, "in which the transcendent enchanted order is made human, even as humans are brought into humbling contact with it" (p. 36).

(Section 4: Science & Magic in Marvel, Sub-section: Techno-magic)

⇒ "Like traditional attitudes to magic, as both a potential source of help, but because of its powerful and uncontrollable nature also a source of trouble, the attitudes toward science and technology are ambivalent" (p. 37, ¶ 4) [Meaning ascribed to science *products*]

- Progress as technological innovation and greater attainment of valid knowledge of reality (via the scientific method) is the literal and metaphorical means of journeying from the "profane" (inferior, conventional) to the "sacred" (superior, extra-ordinary) (¶ 1 & 2). [Meaning: Science *processes* yield *products* that are world altering—that transform the profane to the sacred.]
- "Super-hero comics display the adulation of technology that Whitehead associates with positivism" (p. 37, ¶ 3). Technological tools act as magical agents (machina ex deus… machine from God) to resolve story lines (e.g. a high-tech gadget to get the hero out of trouble) (¶ 3). [Meaning: Science *products* save the day.]

⇒ "Three ways in which troubles with science appear are: concern over cosmic indifference; resistance to technological determinism; and mad scientists" (p. 37, ¶ 4) [Meaning & structure: Science is neutral in its indifferent stance (*process*). Technological *products* that mechanizes humans and humanizes machines call into question the proper boundaries between humans and technologies—society and machines. Scientist representations move beyond stereotypical.]

(Section 4: Science & Magic in Marvel, Sub-section: Cosmic indifference)

⇒ Science's utilitarian [Structure] view renders human life and work meaningless [Meaning].

⇒ Cosmic indifference expresses a notion of efficiency and the reduction of all things to a single measure (p. 38, ¶ 1) [Meaning]

⇒ Themes reminiscent of C. P. Snow's 1964 "two cultures": Scientism vs. humanities

- Cosmic beings (as a metaphor for science embodied) are indifferent of their powerful effects on 'mere mortals' (¶ 1).

(Section 4: Science & Magic in Marvel, Sub-section: Technological reductionism)

⇒ Isolation and alienation are the prices paid for the modern condition of technological dependence (p. 38, ¶ 1) [Meanings ascribed to technological dependence].

⇒ Humans struggle with resistance to technological control (¶ 2) [Meaning]. There is “something essentially human that defies measurement and resists calculative force” (p. 39, ¶ 3) [Structure: Not everything is permeable to science’s gaze.]

⇒ The question recurs of the proper relation between machines and society—of the proper boundary between humans and technology (p. 39, ¶ 5) [Interplay of structure and meaning].

- Deathlok (1974) is bionic “person” who struggles to override the computer’s control of his actions (¶ 2).
- The super-villain “Mad” Thinker is the image of arch-positivism, using advanced computer technology to predict human behaviour but repeatedly fails because of the human “X” factor (¶ 3).
- Warlock is a “sentient form of ‘techno-organic’ life which resembles circuitry and machinery” (p. 39) and who struggles against “the ‘scientist’ view of life as essentially a form of matter reducible to energy” (p. 39).

(Section 4: Science & Magic in Marvel, Sub-section: Scientists)

⇒ The “pop” scientist is not a simple stereotype, but a *complex of possible stereotypes*, a repertoire of features that may be drawn on selectively to depict a range of scientist-types to suit the specific role intended [hero, villain, or a well-intentioned person prone to judgment errors]” (p. 40, ¶ 4) [Structure of experience of *scientist* and meanings ascribed].

- Basalla’s (1976, p. 263) content analysis of images of scientists in popular culture (including references to super-hero comics) describes the scientist as a dangerous figure who tends toward mental instability and social irresponsibility (p. 40).

⇒ The scientist can be a devoted family man and friend of the forces of good who makes the mistake of tampering “with forces of nature which must not be tampered with” (p. 40) [Structure & meaning of what *scientists* do and the motivations behind their actions].

⇒ Scientists can be good or bad. “Savior-scientists” correct the ill effects (intentional or not) of misguided scientists (¶ 3) [How structured & What meaning].

- Dr. Curt Connors, in trying to regenerate lost limbs (reptilian model) to help people, himself becomes a lizard. Science itself is used to correct the condition (Spiderman creates antidote from original research) (¶ 2).

⇒ It takes science to correct science. (¶ 3) [Structure and meaning ascribed to *processes* of science.]

- "Like much other science fiction, the Lizard's story is about the hope of science and its tragedy, its potential and capacity to produce both good and bad… from apparently the same source… [S]cience is both the source of trouble and its (literal!) solution… symbolizing ecological problems that are caused, but must also be solved, by science" (p. 40).

⇒ Note that, in Locke's reading, science causes the problems. This is different than saying that humans cause problems in their misuse of science. The culprit is science and not the human, even though it is the scientist that enacts the misuse [Meaning ascribed to science via the scientist. Scientist & society can be victims of science's blunders].

⇒ The evil scientist (counter-figure to the savior-scientist) suffers general alienation, is often disfigured (an unsightly aberration of nature), and carries *him*self (almost, if not always, male) with an air of pronounced arrogance and self-declared indifference to the plight of humans (¶ 5). As alchemist, he breaches the boundary between science and magic as he conducts forbidden experiments in a search for knowledge as power to position himself above society's rules (¶ 6). [Meaning: Science processes breech forbidden bounds (See Coyle & Fairweather models).] [Reminiscent of fallen archangels and Adam & Eve's temptation to eat of the tree of knowledge and fall out of goodness and God's favour… Elements of religion as thought-stopping.]

- Dr. Doom, the archenemy of the foremost savior-scientist figure (Reed Richards) is the classic Faustian figure who sells his soul to the devil. Working on forbidden experiments he is scarred physically and mentally so that he lives sealed literally and figuratively in sealed armor.

⇒ Science is privileged. [Structure: Process] The perceived tension of science's social exclusivity sees science's (and scientists') behaviors as inherently risky with the mundane masses destined to shoulder science's inevitable blunders (p. 42). [Meaning: Process]

⇒ Science as the purified "sacred" realm of Enlightened modernism [Meaning: process] contrasts against the profane which it seen to have produced [Meaning: product]: an oppressed world of manual laborers existing in a realm wrought out of industrial techno-science (¶7). [Structure & meaning]

- Savior-scientist Reed Richards' experimental star ship's test flight exposed his friend, test pilot, Ben Grimm to cosmic rays. Grimm, from an impoverished background in Manhattan's Lower Eastside becomes a monstrous thing, while Richards, the son of a wealthy science-inventor, is the archetypal handsome, intelligent white-collar college-boy (¶ 7).

(Section 5: Conclusion)

⇒ Popular representations of science are more complex than the overly simple formulas worked by academics regarding the way science "affects" people (p. 42). [How structured]

⇒ The disenchantment-enchantment formulas do not capture the complexity of representations of science in super-hero comics (¶ 1). [How]

⇒ Science appears sacred, extra-ordinary, and more than human in representations of cosmic entities that embody a cosmological order in a personalized character (¶ 1). [How structured]

⇒ Science is like magic and it is not an unalloyed good or an unqualified power. As it displaces a sense of value in the mundane human world with an attitude of indifference, it becomes a source of alienation and thus disenchantment (¶ 1). [How structured]

⇒ Similarly, technology is complex (¶ 2). [How structured]

⇒ It affords a means of contacting the sacred cosmological order: [How structured & What meaning]

- to attain super-status;
- to take a journey; or
- as *machina ex deus*

⇒ At the same time technology is a source of trouble: [How structured & What meaning]

- loss of humanity
- worry over human-machine boundaries
- question of the proper place of machines in society

⇒ Similarly, scientists are complex (¶ 3). [How structured]

⇒ Whether savior-hero or mad villain, neither are unequivocal and either might bring harm by factors beyond science's capacity to control

⇒ "Science and the scientist are never simply one thing… but multiple, mixed, and moveable" (p. 42, ¶ 4).

For the purposes of this thesis, and to therefore make transparent the move from the above summative document to an ensuing phenomenographic model, I have introduced an intermediary document that represents the culling, collation, and sorting of key ideas into a more concise summary. I now present and discuss this summary in sections, again using the textbox format.

<u>Excerpts, key words, and ideas extracted & distilled from the summative document</u>:

<u>Over-riding theme</u>: ambivalence about science, technology, and scientists in pop culture of super-hero comics reflects ambivalence in academic discourses

Locke's introduction and conclusion confirm and reinforce an overriding theme of ambivalent experience of science, technology, and scientists—both in the popular culture of super-hero comics and in academic discourses about science and culture. Phenomenographically speaking, Locke affirms the variable public experience of science, technology, and scientists. He further positions science amid other ways of knowing and, in so doing, he both describes the external horizon of science and begins a structure of awareness of science as a producer of explanations. Notably, the methods and processes of science are as hidden and as mysterious as the privileged ways of magic and mysticism. Locke describes cosmic beings as "science embodied"—threatening with their combinations of power and indifference.

- science...
    - coexists with other ways of knowing (structure: external horizon)
        - the scientifically unexplainable implicates the mystical (rather than thinking of the unexplainable as an occurrence whose naturalized explanation is as yet not known)
        - science is a hole filler (intellectual rationalization)
    - connects a mystical, magical, spiritual world with an everyday one (linkage between internal & external horizon)
        - accesses power of the magical
        - interjects the magical into the everyday
        - privileged – the purified "sacred" realm of Enlightened modernism
        - cosmic beings are science embodied.

The public intersects with science at the level of products, not of processes. Characteristics of past, present, and possible future products of science overshadow its processes in the structure and meaning of awareness. A cloak of cold, impartiality both obscures and characterizes scientific processes. As cosmic being, science becomes unmoved, unaffected, *neutral observer* of humanity and the world.

- science...
  - powerful and threatening – science (not scientists) is responsible for its blunders (meaning ascribed to science)
    - can produce freaks of nature
    - power calls for "great responsibility"
    - uncontrollable nature; force not to be trusted
    - it takes science to correct science
    - three areas of concern: cosmic indifference; technological determinism; & mad scientists
  - neutral tool
    - but powerful (& potentially corrupting)
    - acquires meaning according to the hand that wields it
  - processes hidden (structure) making science enchanted & distant (meaning)
    - "magical" ability (due to inaccessibility of process) to explain away the unexplainable (disenchanting)
    - prioritizes efficiency and reduces all things to a single measure

At the same time, science's products make it an *active force* in the world. In super-hero comics, as in everyday life, science's explanatory and technological products sit at the core of the structure of awareness of science. Moreover, meanings ascribed to science have everything to do with public perception about its material and knowledge products—these constituting the distinguishing features that hold science together as different from non-science.

- science implicated as both *neutral observer* and *active force* (structure of awareness forms the framework here, while the subsidiary points speak mostly to the meaning)
  - neutral observer
    - cosmic indifference of the cosmic being –
    - utilitarian view renders human life & work meaningless
  - active force: set of potentials & possibilities to produce explanations & technological tools
    - provides explanatory force (technological rationalization) for linking the sacred (mystic) and the profane (everyday) e.g. explains source of superhero powers
    - creates that which is other worldly, including scientists who then watch dispassionately the effects of science's processes and products
    - products are world altering (transform profane to the sacred)
      - products can save the day
    - technological tools act as magical agents
    - technological dependence produces isolation and alienation (loss of humanity) … but humans defy measurement and calculative force
    - sentient form of techno-organic life (technological reduction): question of appropriate boundaries between machines and society
    - means of contacting the sacred cosmological order
      - means to attain super-status
      - means to take a journey
      - solution to a problem (saves the day – *machina ex deus*)

Finally, on the matter of scientists, Locke consistently describes them as humans at play with a powerful dangerous tool. Though privileged in their knowledge of science, they remain always human. According to Locke, in super-hero comics, as in real life, scientists come in all manner of person. They have no distinguishing feature other than their access to the workings of science. As such, they do not define science; if anything, science defines them.

- scientists (not the same as “indifferent” cosmic being)
    - imperfect humans who tamper with forces of nature
    - can be made corrupt by dabbling with such a powerful tool
    - can themselves be victims of science’s blunders
    - party to the privileged realm of science
    - not a simple stereotype...
        - all the variability and vulnerabilities of humans show up in scientists
        - good... bad... mistaken... family type... recluse... saviour... villain...

From the above data, it is possible to formulate a phenomenographic description of the structure and meaning of science in super-hero comics as presented in Simon Locke’s analysis. Such a description follows. In the reading, recall the purpose of the present thesis: to provide an illustrative phenomenographic case study and to suggest a means for subsequently using the literature to generate a comprehensive mapping of the public understanding of science. The phenomenographic description that follows, informed by only one study, is a necessarily rudimentary and premature offering. Yet, for the data that was available, it is one description that can be—indeed, has been—argued for. Such a humble offering is therefore both intent and product of this current work and can only be taken in that light.

Shaping an Awareness of Science Through a Phenomenographic Lens

A description of the *structure of awareness* of science evidenced in Locke’s reading of super-hero comics illustrates the particular kinds of findings that emerge when a phenomenographic lens is taken to interpretation. Data, similarly extracted from three other studies (drawn in no particular order or precedence), subsequently suggests how the current reading might evolve in conjunction with future phenomenographic analyses.

Detailing the Experience of Science Represented in Super-Hero Comics

The social representations of a phenomenon—in this case, science as represented in super-hero comics—speak to and from the experience of that phenomenon in culture at large (Moscovici, 1988) and, in the present case, Anglo-American culture in particular (Locke, 2005). In his analysis, Locke considers the products, processes, and expert workers of science—three prime candidates for phenomenographic *categories of experience*. However, the data as collated in the above summative document, when subsequently sorted according to these categories, (see "Excerpts, key words, and ideas extracted from the summative document") gave up a theme of science as producer at the centre of Locke's discourse. That is, Locke details how the knowledge and material *products* of science figure in a central way amid manifestations of science in super-hero comics—the processes and expert workers acquiring significance only in relation to these products. Indeed, science-fictional accounts are mostly silent when it comes to explicating the individual and collaborative methods of science and scientists. Instead, science's processes and expert workers appear to operate in solitary, mysterious places—a characteristic that, as shall be seen, lends meaning, but less-so structure, to an awareness of *science as producer*.

First Face of Variation: Enchantment, Disenchantment, Multiple Meanings, and a Tentative Category of Experience

Super-hero comics constitute one arena where broad cultural concerns and meanings of science are actively worked out. Locke juxtaposes these discourses with other shared cultural rhetorics about science and finds the same ambivalences surrounding the "dilemmas posed by the rise of science and the manner in which it is represented" (p. 28).

Science's power and prestige owes to its ability to provide explanations based on the natural world and, from such knowledge, to generate technologies capable of transforming that world. In their capacity to rationalize the mysterious, the knowledge products of science can legitimize things otherworldly. They are used to *explain away* a fantastical *supra*natural[37] universe. For example, science transforms an eclipse of the sun from something mysterious and unexplainable to an event consistent with the natural laws of the planet. Accordingly, knowledge products disenchant. Conversely, in technology's ability to create the mysterious—for example in unraveling the human genome and in producing cloned creatures—the material products of science enable a world other than the natural. They *create* a fantastical *supra*natural universe. In this way, technological products enchant.

[37] The term *supra*natural captures the notion of all things other than that which is found to exist in the natural world. Such otherworldly entities need not be supernatural; that is, they can be non-natural without having special powers. For example, mythical creatures like ogres and dwarves do not have special supernatural powers, but there is no evidence of these creatures actually existing. On the other hand, the duck-billed platypus were it not an actual creature could be a prime example of a supranatural (neither supernatural nor natural) life form.

Ironically, although science is *of* the natural world, its technological products are not. Indeed, as Locke further points out, the disenchanting-enchanting dichotomy—also, characteristic of academic discourses about popular science—oversimplifies. Knowledge is both a tool for creating technologies and a product of such technologies. The interplay of science's products, in both super-hero comics and popular science in general, creates a complex public understanding of science that deviates drastically from canonical assumptions about science's monolithic impact on a passive or merely reactive public. The public uptake of science shows itself as active and multiplex. As a set of potentials and possibilities toward either enchantment or disenchantment the varied articulations of science provide "alternative rhetorical resources that can be employed to present particular descriptions of science for different argumentative purposes" (p. 28). The category of experience of *science as producer* lends itself to a public understanding of science that is both malleable and versatile.

As introduced previously, the processes, products, and expert workers of science do not parse into distinct phenomenographic categories of experience. The dual products of knowledge and technology—encountered as world altering and world creating—overshadow and reflexively assign meaning to science's hidden processes and expert workers. Indeed, in humans-made-extraordinary, technologies and naturalized explanations render super-heroes "fantastically reasonable." Thus, though science appears malleable in its public uptake, Locke's analysis, suggests but one tentative *category of experience* in an as-yet-to-be-determined *outcome space* that would ultimately map the public understanding of science. The description below captures the intra-awareness variation of a tentative thematic category of *science as producer*.

Second Face of Variation: The Structural and Relational Awareness of Science as Producer

Science in super-hero comics distinguishes itself by providing explanations and models that parallel recognizable natural world occurrences. Drawing from the stock of accepted scientific theories, these explanations and models operate as hole-fillers to make loose sense of a fictional *supra*natural universe. At the same time, *science as producer* co-exists in a universal and continuous reality of magic, religion, myth, legend, and folklore. Residing in the external horizon of *science as producer*, these alternative parallel themes differ in magical, non-naturalized, explanatory narratives and natural, non-technological, products that respectively contrast against science's naturalized explanations and technological tools.

Scientific knowledge—transferred from known contexts to hypothetical ones—makes metaphorical sense in explaining the origins of super-hero powers. For example, knowing there exists living creatures that undergo physical metamorphosis, a rationale is built for the Hulk, who transforms from man to super-hero—presumably as the result of hormonal changes associated with intense emotions. Likewise, nuclear radiation genetically modifies a "superspider" that subsequently bites Peter Parker infecting him with its powers. The story of Spiderman begins. And, when a superior race of humans develops the scientific and technological means to elevate base characteristics to God-like qualities, Superman appears. Notably, naturalized explanations, and *not* empirically grounded data, sit at the core of *science as producer*.

In mystical, magical ways, super-heroes “represent the vision of hidden power that science promises to release and control” (p. 36). With their origin stories, these heroes at once embody the humanization of an alien world of scientific objects and the “scientization” of a human, everyday world. Science processes can equivocally move us to a perfect world or tear down and destroy the one we cherish.

Alongside scientific explanation, technological tools share a central position in the structure and meaning of awareness of *science as producer*. Like magic, technology’s powerful but uncontrollable nature is source of both worry and wonderment (p. 37). Through technology, science both creates and solves problems. Moreover, technological and scientific processes provide the physical and metaphorical means whereby super-heroes journey from mundane, ordinary, everyday places to “sacred” realms (p. 31). These transformations appear as a kind of magic, understood (if at all) by only a privileged few. A prime example exists in Reed Richards, brilliant scientist-inventor and leader of the *Fantastic Four,* who “frequently rustles up a convenient high-tech gadget to get the group… out of trouble” (p. 37). Yet, Richards’ experimental “star ship” exposes friend Ben Grimm to cosmic rays, creating of Grimm a monstrous creature. Richards, the archetypal rich college-boy, contrasts against Grimm, the product of an impoverished background in Manhattan’s Lower East Side. In this pairing, the tension of science’s social exclusivity plays out. And, though it takes science to correct science, Richards, the scientific genius is powerless to help his friend. Holding the key to Pandora’s Box, the humanly flawed scientist connects to the powerful but is not himself powerful. Thus, the elite and privileged scientist, intentions aside, can and does produce things profane. In like manner, the mundane masses are made to bear the burden of science's blunders (p. 42).

Recognized and judged as both explanatory force and empowering tool, science's products define the core of the structure of awareness of *science as producer*. Relationally speaking, these products can engender both ambivalence and awe—trepidation and adulation. Obscure but powerful processes appear inaccessible except to expert workers—themselves mere humans operating under a directive of objective, depersonalized neutrality. As technologies reduce human and social beings to one-dimensional, measurable, machine-like entities, a reputation of calculating indifference affirms a scientific attitude toward human life as meaningless. In super-hero comics and everyday places, the secret workings of *science as producer* alienate and mystify.

Phenomenographically speaking, the workings and methods of science constitute vague unknowns cloaked within the structure of *science as producer* and recognizable only according to agreed upon cultural signs and symbols. Two consequences result. The first admits into science's thematic field both empirically-based and non-empirically based knowledge and material products. The second promotes a skeptic anti-science sentiment.

If the institution of science defines itself according to its empirical processes, and not its products, and if these processes become increasingly obscure or varied from traditional representations, then a public awareness of *science as producer* fails to sufficiently distinguish science from non-science on science's terms. Thus, at the boundaries of *science as producer,* one encounters, by definition of this category of experience, knowledge and material products that bear less and less of a resemblance to the familiar pure and hard sciences of, for example, science educational curricula. Conversely, things that look and feel like science by virtue of their knowledge and material products—and irrespective of method or accreditation by scientific institutions—sit comfortably within science's internal horizon. In short, if science is understood as producer, packaging and marketing counts!

Second, if the processes of science are seen to operate in mysterious magic-like ways and if scientists—whether of the mad, everyday, or savior-hero type—are as susceptible and humanly frail as the rest of us, then science becomes a frighteningly potent force capable of inflicting irreversible damage on the natural world. Locke demonstrates how, in autonomous, impartial, and pantheon-like fashion, the scientists of super-hero comics wield uncanny and reckless power. Metaphorically speaking then, scientists, in the conception of *science as producer,* are humans indifferently at play with magic.

Exploring the Implications of a Public Awareness of Science as Producer

If science is known by its products, and if these products include accessible theories and models as well as technological tools, then undecipherable empirical processes figure out of the public experience of science. In public conception, science need not be forged out of any interaction of Baconian empiricism and Cartesian rationalism. Indeed, in public forums, science appears more metaphysical than empirical. It becomes a meeting of fantasy and reason where reason is brought to bear on all things natural, supernatural, and *supra*natural. The experienced fantastical world exists a priori. In super-hero comics, storylines begin with the premise of a world that has magical beings, then the signs and symbols of science—its recognizable products—are called upon, where plausible, to fashion explanations and justifications. Concern is less toward an accurate representation of science's processes or its institutional practices and more toward the issue of plausibility; that is, to explanations and technologies that can be believed. As in other expressions of science in fiction, the science of super-hero comics occupies a place alongside a broad spectrum of world-making cultural resources including magic, religion, myth, legend, and folklore.

What are the implications of a public understanding of science that, in definition, prioritizes products and shuffles processes and expert workers to the relational sidelines? If science is supposed, understood, and expected to restrict its production to explanations and technologies, then one might expect resistance to advice from ecological sciences about how one should conduct one's life—for example, in the case of directives to lessen the rate of global warming. Science does not and therefore ought not advise. It only explains. Likewise, the social sciences do not offer traditional recognizable science products. Behavioral, anthropological, and social models, though interesting, are not sufficiently distinguishable from folk psychology and socially accepted wisdom. Explanations arising out of the social sciences suffer from everyone already having an opinion. Either a social theory affirms common knowledge—in which case, "What advantage does the theory offer?"—or, the theory seems counterintuitive and is rejected out-of-hand. Social science products tend to be relegated in public consciousness to the stuff of entertainment and parlor games.

As illustrated in the preceding paragraphs, a model of awareness of *science as producer* offers implications about the public uptake of science. That said, such musings, while interesting as thought experiments, are pre-emptive. Accordingly, the reader should take them in the light that they are given; that is, as demonstration of how a phenomenographic approach to describing the public awareness science might proceed and how such a model could subsequently inform our understanding of and approach to the multiple and varied challenges associated with science in the world today.

CHAPTER 5. DISCUSSION AND FURTHER AREAS FOR STUDY

Having both articulated a rationale and outlined a means for charting the landscape of the "Public Understanding Of Science," it is prudent to take stock of the research journey thus far and to consider where it might go from here.

In-Flight Observations on an Unfolding Phenomenographic Process

The experience of applying a phenomenographic template to represent the awareness of science is instructive. Formulating a fair depiction of a phenomenon according to distinguishable extra-phenomenal differences and common intra-phenomenal similarities presses a different and insightful way of looking and understanding. The personal phenomenographic depiction was qualitatively different from the tentative one sketched out of Locke's study of super-hero comics. This is promising on two counts. First, it supports the phenomenographic contention that a phenomenon is less captured in sameness of experience than in its variance and in the structure of that variance. Second, it suggests that the structure provided by a phenomenographic lens might resist confounding effects of researcher bias. Certainly, there was a sense of that in this researcher's limited experience.

A Promising Forward Glance

A brief look at data collected from three other studies of the public understanding of science foreshadows the manner in which a full-blown phenomenographic study might proceed. Prior to any attempts at conceptualizing the nature of awareness of science evidenced in Locke's reading of super-hero comics, I undertook the initial phases of data collection on these three studies. Looking back, they promise to support, enrich, and expand on the beginning map sketched in the present illustrative case. Carvalho (2007, April) considers varying ideological cultures and evolving media discourses about climate change in three British "quality" newspapers from 1985 to 2001. Her analysis strengthens an image of science knowledge products as selectively and malleably suited to multiple and conflicting ideologies. In "Vernacular Science Knowledge" (2007, January) Wagner uses a "longitudinal and cross-sectional study of biotechnology's reception in Europe" (p. 11) to track the evolution of discourse on new science phenomena. Everyday communication begins from multiple interpretations, metaphors, and images and ultimately converges on a few shared narratives that frame science in intelligible, concrete, causal, everyday terms (p. 9) not unlike those encountered in super-hero comics. Partaking in the web of everyday discourse about science, and learning to operate techno-gadgets, reduces anxiety about technoscience while promoting social inclusion and access to the symbolic power of knowing. Vernacular science knowledge makes accessible and provides a means for staying close to the not-to-be-trusted products of science.

Finally, Coyle and Fairweather (2005, April) investigated the public reception of biotechnology in New Zealand through qualitative analyses of 117 participants in 11 nationwide focus groups. The researchers explored the meanings of various idealized "natures to participants, and the ways they impact upon how people draw boundary lines between 'natural and unnatural/artificial' and how these boundary lines in turn impact upon the acceptability of new biotechnologies" (p. 145). Their work thickens an awareness of science as producer of non-natural technologies. Seen as scientific interventions or science-in-action products, the participants experienced the biotechnologies of genetic engineering, xenotransplantation, and stem cell research as unnatural products of science.

> Discussions about ‘desirable’ or ‘appropriate’ natures... [were] compared to the futures offered by novel biotechnologies, and used as a basis from which to determine their acceptability…. [P]eoples’ hopes, fears, concerns and engagement with ‘natures’ connect[ed] to the wider societal concerns of the impact of globalization on New Zealand (p. 144).

In this manner, a case is built for an external horizon of wise, traditional, pure, complex, and balanced chronotopes of nature that by contrast confer meaning onto the internal horizon of science and its unnatural biotechnological products.

Implications and Future Considerations

In overlooking science’s various natures and accessibilities, a deficit perspective misses the complexity of problems associated with the role of science in society. Remedial action bent at better educating an uninformed public have not addressed the rudimentary issues. A full phenomenographic mapping of the experience of science promises to provide a much-needed baseline for grappling with the intricacies of science at play in public and private places. Preliminary considerations reveal that, in various instances and contexts, people alternatively fear, revere, and revile science for its privilege and unquestionable power over our world. What can and should be done about this?

If science is understood primarily as producer of explanations and technologies, then does a lesson on the tentativeness of its offerings foster uncertainty and dismay or can it improve public understanding? Should and could science be broadly understood as something beyond producer? How much faith can be placed in the individual and institutional practices of science? Can people learn more about these practices and develop the ability to make informed decisions about the reliability of directives given in the name of science?

How should scientific explanations sit alongside other authorities on the nature of this world? Does science have a legitimate place in advising people on political, ethical, or ecological matters? Can these matters even be separated? Can science restrict itself to predicting, to varying degrees of certainty, the consequences of human action? Would a public feel comfortable and able to understand such descriptions? And, recognizing the complexity of our world, how much dare we rely on scientific predictions and how wise are we to revert to instinct and intuition?

I offer more questions than answers. In a complex world, in vitro solutions don’t work well, leastwise not often in the directions we predict. If we desire a mindful co-evolution of science, culture, and the world, then surely a picture of what science currently is to people would help locate us. It makes sense—common or otherwise—that by locating where we are, we might be better positioned to consider in what direction we are pointing, where we can and wish to go, and how we might proceed on that collective journey. Such awareness is crucial to properly negotiating the schooling of science. Simple Bandaid fixes treat symptoms while obscuring rudimentary and pivotal leverage points for insightfully articulating curricular design and teacher development with pressing issues in the interplay of science and the natural world—issues that, in some way or other, fundamentally concern us all.

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