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Interdisciplinary research and academic sustainability: managing knowledge in an age of accountability

THEMATIC SECTION
Interdisciplinary Progress in Environmental Science & Management

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SUMMARY

For the past 125 years the university has been the home of knowledge production. The 20th century research university combined a Kantian belief in disciplinarity, a Humboldtian commitment to linking research and education and upholding academic autonomy, and a Cartesian allegiance to infinite knowledge production. This approach to knowledge creation was seen as sufficient, for knowledge products themselves were understood as automatically relevant to society, and no one imagined a problem with endless knowledge production. The 20th century model of knowledge production is now under pressure from a number of sources: information technologies, neoliberal assumptions and demands for greater accountability. 'Interdisciplinarity' has become the term of art for addressing this crisis. But interdisciplinarity is no panacea to the challenges facing knowledge production today. In addition to knowledge on sustainability, knowledge production itself must now be made sustainable. This requires clearly connecting knowledge production and use, and ending the bad infinity of knowledge production.

Keywords: interdisciplinarity, sustainability, university

INTRODUCTION

Knowledge production is widely viewed as the engine driving 21st century society. As the phrase goes, 21st century culture is a 'knowledge society'. Of course, every culture is a knowledge society; living by knowledge rather than instinct is a distinctive trait of the human species. But the term is nonetheless expressive, in that knowledge production has been systematized and institutionalized, reinforcing the belief that societal and environmental problems can be solved through the production of additional knowledge.

New knowledge, however, produces both winners and losers, and results in social disruption as well as societal progress. Computer-generated algorithms rattle stock exchanges and undermine regimes. Individuals, corporations and countries, thrown into a market now global in extent, struggle to maintain position (Friedman 2007; Lewis 2010). Moreover, the efficacy of additional knowledge is often unclear. The USA has spent tens of billions of dollars on climate science research, but with no clear policy outcomes, while the budget for the USA's National Institutes of Health has doubled at the same time that the USA rates for infant mortality and life expectancy have stagnated (Anderson & Chalkidou 2008). Yet despite constant upheavals (as Karl Marx [1848] stated, 'all that is solid melts into air') and yawning gaps between inputs and outcomes, there is still little reflection on basic assumptions underlying knowledge production such as, is additional knowledge the solution to our problems? And, should there be limits to knowledge production (but see Shattuck 1997 and Stehr 2006)?

Where does the university fit into all this? Whether attention is directed toward environmental matters, or to issues of health care or national security, the same concern may be identified: can colleges and universities meet the changing demands of society? Some see the university as doomed to irrelevance (for example see Cronin & Horton 2009). Knowledge has been let loose upon the world, and is now created democratically, via millions of nodes; the university is a dinosaur that reacts too slowly to these changing rhythms. Yet, despite the explosive growth and ubiquitous presence of Google and Wikipedia, RSS feeds and citizen journalists, the research university still remains the home of knowledge production and dissemination. Nonetheless, it seems clear that the university will not retain its privileged position without substantial reform (for example see Taylor 2010).

This paper offers an account of the state of knowledge production in the early 21st century. It describes the limitations of current disciplinary structures, and focuses on the promise of interdisciplinarity to help the research university adapt to changing social demands and conditions. Concerns with the current state of knowledge production are commonly voiced, and a wide range of solutions have been offered, many of them tied to notions of interdisciplinarity and transdisciplinarity. These suggestions represent a step in the right direction, but the simple focus on interdisciplinary research and education is insufficient to address the challenges society faces. Interdisciplinary approaches to knowledge need to be thought through in a fundamental way if they are not to recapitulate the problems of disciplinary knowledge. In particular, interdisciplinarity needs to be placed within an

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environmental context, linking future knowledge production to the concept of sustainability.

Linking interdisciplinarity to sustainability will require a significant reformulation of the underlying assumptions of the 21st century university. Interdisciplining university culture to make knowledge production sustainable, rather than simply calling for more knowledge production on the subject of sustainability, will require challenging deeply engrained ideas about the nature of knowledge production, such as changing the definition of what counts as academic rigour.

Before proceeding to this argument I offer a few words of definition. Interdisciplinary approaches to research or education are marked by the integration of different disciplinary approaches or methodologies, whether in terms of narrow (for example chemists and chemical engineers) or wide (natural scientists working with social scientists or humanists) interdisciplinarity (Frodeman & Mitcham 2007; Klein 2010). This is in contrast to multidisciplinary approaches, which make little or no effort to integrate different data sets, approaches or fields. Transdisciplinarity approaches are those that move beyond the university to engage members of society. It is possible to be interdisciplinary without being transdisciplinary, and vice versa: for instance, the insights of a single discipline may be useful to a government agency or stakeholder group. A premium, however, should be put on creating interdisciplinary knowledge for transdisciplinary reasons, to improve the relationship between the production and use of knowledge.

THE STATE OF THINGS TODAY

Academics should be wary of positing a past golden age of university life. Nevertheless, the academy does seem particularly beset by problems today. These problems are at once economic, technological and political in nature. To begin with, the numbers are not favourable: to take the USA as an example, at the federal level the USA faces a US$ 1.3 trillion annual budget deficit, putting pressure on all discretionary spending. At the state level, support for higher education is down by a third since 1970, as higher education is increasingly viewed as a personal investment rather than a public good. In the state of Colorado, for instance, state support for higher education has decreased 70% since 1980, and there is talk of cutting state support altogether (Rork 2010). Many liberal arts colleges today cost US$ 40–50 thousand per year, and state schools are not much less costly: tuition, room and board approaches US$ 20 000 per year at most public institutions (for example, out of state tuition at the University of Michigan is the same as tuition at Princeton). The numbers are also grim elsewhere: In October 2010, UK government announced higher education cuts of 40% in England over the next four years (Labi & McMurtrie 2010). Higher education is being squeezed between higher costs for equipment and facilities, a declining student pool, public sentiment against tax increases of any kind, and budget deficits at the state and federal level.

At the same time universities are being pressured by technological change. Distance education and online courses are now commonplace. Private, for-profit entities are booming: the University of Phoenix is now the largest university in the USA in terms of enrolment. No major university has yet set up a full suite of courses on line, though both Columbia University and Massachusetts Institute of Technology (MIT) have experimented with virtual courses. But like the music industry in 2000, universities may simply be waiting for their own version of Napster, a 'killer app' that upends the current business model of the university. 'Name' institutions should be able to adapt; but lesser known institutions and 'directional universities' (for example, my own institution, the University of North Texas) could find themselves without a viable future.

Finally, the university faces demands for greater social accountability. Every academic is well aware of the increasing amounts of time absorbed by evaluations and the documentation of productivity. Neoliberal assumptions, where bottom line concerns trump traditional calls for the role of the university in the preservation of cultural inheritance, have become the norm. At Texas A&M University, for instance, professors are now scored in termed of their cash value, their salary balanced against grants brought in and number of students taught per class (Mangan 2010). And while 'accountability' is typically defined in terms of economic outputs, there is also an increasing recognition that academic research must have clear policy and cultural outcomes as well.

Setting aside these external drivers, the research system itself creaks under the weight of business as usual. The sheer volume of knowledge produced is overwhelming. In 2009, researchers found that only 40% of the papers published in prominent science journals between 2002 and 2006 were cited in the first five years after publication (Bauerlein 2010). Refereed academic publications grow at a rate of more than 3% a year, a doubling rate of twenty years. Bauerlein titled his article 'We must stop the avalanche of low-quality research', but the problem isn't low quality; it is the general overproduction of knowledge. Driven by technology (increasing accessibility via the web; searchable databases) and academic population growth, knowledge production follows no Aristotelian mean, but rather proceeds on a trajectory of infinite growth.

Bauerlein (2010) noted that 'Senior physics professors have well-financed labs with five to 10 PhD-student researchers. Since the latter increasingly need more publications to compete for academic jobs, the number of published pages keeps climbing.' As does, of course, the number of PhDs. But what is the overall model here? Is the current system of knowledge production sustainable, in terms of either articles or researchers? Will knowledge production be the first example of exponential growth that does not come to an end? Or are plans for a smooth transition to a steady state of knowledge production needed (Daly 2008)?

THE PROBLEM OF DISCIPLINES

For 150 years knowledge production has been managed by division, by creating disciplines and subdisciplines. It is an approach rooted in a set of deeply engrained commitments. The 20th century university combined a Kantian belief in disciplinarity with a Humboldtian commitment to linking knowledge production and consumption in terms of research and education. These assumptions were in turn built upon a sense of the potential infinity of knowledge production that looks back to Descartes' work in the early part of the 17th century.

Immanuel Kant laid out the argument for specialization and expertise more than 200 years ago in 1785, stating that 'All industries, crafts, and arts have gained by the division of labor, viz., one man does not do everything, but each confines himself to a certain kind of work that is distinguished from all other kinds by the treatment it requires, so that the work may be done with the highest perfection and the greatest ease. Where work is not so distinguished and divided, where everyone is a jack of all trades, there industry remains sunk in the greatest barbarism'(Kant 1997).

Kant heralded the breakdown of a long established tradition where professors ascended through a hierarchically arranged set of faculties across their career, from philosophy (or the humanities) to medicine, law, and with luck eventually to theology (Clark 2006). Now disciplinary specialization became a sign of intellectual seriousness. Educational reformer Wilhelm von Humboldt linked research to teaching, two tasks that hitherto had often been distinct. Scholars now had an internal market for their productions (other professors and students), which served to de-emphasize connections to the larger society. This new focus was matched with Humboldt's emphasis on the autonomous nature of scholarship. Humboldt based academic freedom, the essential condition of knowledge production, in institutional commitments to *einsamkeit* (solitude) and *freiheit* (freedom) (Krull 2005). The scholar's social responsibilities were thus delimited to teaching and research, the latter set by disciplinary standards for quality scholarship.

Permeating this entire edifice was the modernist belief in the beneficence of infinite knowledge production. Descartes is emblematic here. Despite constant protestations of the orthodoxy of his Christian beliefs, Descartes was regularly charged with atheism, a fact deduced from the position he placed humans in vis-à-vis God. As he put it in the *Rules for the Direction of the Mind* (written in 1701): 'For since the sciences taken all together are identical with human wisdom, which always remains one and the same, however applied to different subjects, and suffers no more differentiation proceeding from them than the light of the sun experiences from the variety of the things which it illuminates, there is no need for minds to be confined at all within limits (Descartes 2000).

Knowledge production was an infinite process that over time would result in insights rivalling those of God. And from the perspective of the 17th century, the accomplishments of the last 300 years do seem to storm the heavens: global telecommunications, organ transplants, the unravelling of the human genome, travel to distant worlds. The modern attitude toward knowledge production is exemplified by Ray Kurzweil, the National Medal of Technology awardee who sees technoscientific progress as both unstoppable and benign. Kurzweil predicts a coming 'singularity' where intelligent machines will design ever more intelligent machines, which will in turn design still more intelligent machines (Kurzweil 1999). And in *Fantastic Voyage: Live Long Enough to Live Forever* (Kurzweil & Grossman 2005), he predicted the devising of means to stop and reverse the ageing process.

The modern university became a closed epistemological circle: knowledge production circulated between researchers, and between researchers and students, reaching the larger world through indirect means. The transmission of knowledge to society was understood as largely automatic in nature, and commonly devalued as 'dissemination', 'outreach' and 'dumbing down'. There was little systematic study of the general problem of translating knowledge to society at large. There was little need; knowledge production and use was thought to have an automatic or 'linear' connection to one another (Pielke & Byerly 1998). New knowledge was by its very nature a good and useful thing; academics could concentrate on its production secure in the knowledge that it would filter into society. This is why, as Sarewitz (2003) noted, science policy debates have overwhelmingly taken the form of science funding debates; since science is inherently a social good the only question concerns the amount of money to put into the system (for exceptions to this general neglect, see Sarewitz 2000, 2004; Nowotny *et al.* 2001; Stehr 2006; Fuller 2009).

The inadequacies of the current regime of knowledge are becoming apparent. But recognizing a problem is one thing, diagnosing it and devising an effective response is another. The university today needs a fundamental analysis of the types of theoretical and institutional change needed in order to move beyond a disciplinary social epistemology of... the modern university.

This, I believe, is the hidden point underlying interest in 'interdisciplinarity'. The term itself is a marker of societal unease, expressing the feeling that current academic behaviour fails to meet present day challenges. The term expresses an absence, conveying dissatisfaction with current modes of knowledge production without a clear sense of how to move forward. It contains a collective unconscious of worries about the changing place of knowledge in society, and conveys a feeling that the university has lost its way. Excessive specialization, lack of societal relevance, and the loss of the sense of the larger purpose of things are tokens of these concerns.

THE MEANINGS OF 'INTERDISCIPLINARITY'

Interdisciplinarity is a boom industry. The term appears in every university strategic plan. It is embraced (if not always funded) by every administrator. And there is a growing community devoted to describing knowledge production that crosses or bridges disciplinary boundaries (interdisciplinarity) and makes knowledge more pertinent to non-academic actors (transdisciplinarity). Among the fruits of these labours are monographs (for example Klein 1990, 2005, 2010; Lattuca 2001; Fuller & Collier 2004; Stehr 2006; Repko 2008), anthologies of reprinted articles (Newell 1998) and collections of original essays (for example Weingart & Stehr 2000; Hirsch Hadorn *et al.* 2008; Frodeman *et al.* 2010).

This research is rich and varied, and has made lasting contributions to understanding challenges to knowledge production and use. It has, for instance, encompassed critical work on the structuring of undergraduate interdisciplinary programmes in fields like gender and environmental studies, and resulted in useful primers on interdisciplinary research and education. But it is also turning interdisciplinarity into its own discipline, codified into an academic product with its own experts, literature, peer-reviewed journals, departments and majors. In so doing, interdisciplinarity is recapitulating the problems that have plagued disciplinary knowledge production: insularity, overproduction, and the lack of relevance and timeliness.

In addition to its virtues, the literature on interdisciplinarity suffers from what Heidegger (1962) called the 'forgetfulness of being'. By this Heidegger meant the contemporary habit of leaping over the more fundamental (and difficult) questions surrounding an issue, to focus instead on easier to address secondary or tertiary issues. Within interdisciplinarity, this manifests itself as the growing focus on the 'how' rather than the 'why' of interdisciplinarity, attending to questions of method and technique rather than struggling to articulate the underlying impulse behind the push for interdisciplinary approaches to knowledge production.

Interdisciplinarity thus falls into a common trap: focusing on means, rather than ends, and debating methodology, rather than larger goals. This move toward questions of means rather than ends is endemic today. As Heidegger (1982) noted in 1954, modern society is characterized by its inability to even ask questions of what constitutes the good life. Questions concerning the ends of life are seen as subjective and impervious to rational discourse; conversations and politics are constructed around increasing the means to pursue the ends of personal choice.

There are at least two problems with this view. In the minds of at least some it is incorrect; values can be treated as approximately as rational as most other matters of thought (self-contained systems such as geometry excepted). But secondly, and more pertinent here, the libertarian view that everyone should be able to pursue their own ends or goals in life is built upon an assumption of an infinity of resources, a position that has become unsustainable. For a society to be sustainable, ends must come to an end; a choice must be made between different ends, since the planet cannot support the infinite pursuit of all ends. And this entails identifying some type of reasonable decision procedure for distinguishing between more and less legitimate ends.

The focus on means and methods has led research into interdisciplinarity into becoming another special science or regional ontology, where it assumes rather than challenges the largest issues concerning knowledge production today. This is an approach that Kuhn called the 'puzzle solving' of normal science (Kuhn 1962). It is likely that the challenges facing the university and society will require that the most basic standards for academic work are altered, for instance lessening the embrace of technical language and citations, while putting more of a premium on rhetorical skills and timeliness (Frodeman *et al.* 2010).

The move beyond the disciplinary epistemology of the 20th century university, and toward a sustainable epistemology, is likely to require three critical elements:

- Understanding the limits of method,
- Redefining academic rigour, and
- Matching knowledge production and use.

The codification of a rigorous methodology is often seen as the holy grail of interdisciplinary research. For instance, Repko (2008) spoke of 'delineating a step-by-step research process that is based in relevant scholarly literature. . .' and of providing 'an easy-to-follow checklist so students can evaluate previous research'. Certainly those who have long laboured on inter- and transdisciplinary problems have useful things to share, but the insights add up to something closer to hard-won wisdom than to a method.

Working across disciplines, and between academia and the users of knowledge, is extraordinarily context-sensitive. Analogies can be drawn from case to case, cautionary tales may be offered, and lessons are there for the taking. But rather than speaking of a step-by-step research process, interdisciplinarity prospers by staying close to cases, expanding a repertoire of skills for dealing with disparate groups in different situations, while resisting the urge for law-like generalizations (Krohn 2010). Guidelines can be quite helpful, especially for students. But 'method' can be discarded once a nuanced understanding of a situation is gained. Overemphasized, methodology makes thinking technological in nature, a cook book recipe to be followed that prioritizes means over ends until discussion of ends simply drops away. The chimera of methodology-talk is the belief that if the correct methodological process is identified the right result is guaranteed. On the contrary, in the final analysis, interdisciplinary thinking, like scientific research itself, is an art that does not rely on predetermined rules.

Across the 20th century, researchers embraced academic rigour and professional expertise as an absolute value. The pursuit of disciplinary rigour has led to ever-expanding numbers of areas of specialization, at the cost of relevance to anyone outside these constricting circles of expertise. Intradisciplinary squabbles, often revolving around narrow methodological debates, become more common than does transformative research. Real-time research and assessment is lost as knowledge products are not produced on the timeline needed by users (Frodeman *et al.* 2010).

To make knowledge products more relevant, values such as timeliness, relevance and cost need to be seen as important as scholarly precision. This in turn requires a rethinking of the nature and limits of expertise. But while there is a growing literature on expertise (for example Crease & Selinger 2006), it does not raise questions of whether academic culture has lost its sense of proportion or pursues an excessive degree of rigour. There has been little theoretical consideration on how to strike the right balance between these often competing values for different situations (but see Fuller 2009). Academic rigour needs to be retheorized to include these competing elements.

Demands for knowledge culture to be more accountable to society are reanimating dormant questions concerning the relationship between knowledge production and use (as well as raising questions about method and rigour, above). Accountability is one of the main drivers of inter- and transdisciplinarity today, and these new approaches to knowledge do increase possibilities for accountability. But accountability needs to be understood in ways that avoid pitfalls such as the bias toward quantification.

The assumptions that have supported the modern university, that knowledge is inherently beneficial, or that scientists and scholars can justify the pursuit of knowledge in terms of 'curiosity' or the innate love of knowledge, now have the faint scent of anachronism. Academic research programmes can be badly out of step with needs on the ground, out of sync with the timelines of decision makers, or of a length that precludes consideration. For example, more than US$ 40 billion have been spent on climate research within the USA since 1990, but this has had little discernable effect on USA climate policy. Climate science continues to be funded at US$ 2 billion per year, though it is unclear what further actionable insights are likely to result (Frodeman 2006). Rather than being driven by a chimerical desire for certainty, this and other research programmes should begin with an understanding of what information is likely to make a difference to policy makers (although it should be noted that the Intergovernmental Panel on Climate Change [IPCC]'s inclusion of a 15 page *Summary for Policymakers* is a gesture in this direction; IPCC 2007).

Accountability, moreover, is more than merely counting. The growing use of bibliometric measures of scholarly productivity raise a number of concerns, including differences in coverage across different disciplines and 'teaching to the test', where research is shaped by the need to increase the individual's H factor (the *h*-index; Hirsch 2005). Interdisciplinary work often shows up quite poorly in these analyses (Wagner *et al.* 2011). Citation analyses need to be balanced with the use of judgment, for example via peer review, and the notion of 'peer' should be expanded to include others beside academic specialists (Holbrook 2010).

In *Beyond Good and Evil*, in the chapter 'We scholars', Friedrich Nietzsche warned of the dangers facing the philosophic spirit, 'The dangers for a philosopher's development are indeed so manifold today that one may doubt whether this fruit can still ripen at all. The scope and the tower-building of the sciences has grown to be enormous, and with this the probability that the philosopher grows weary while still learning or allows himself to be detained somewhere to become a 'specialist: so he never attains his proper level, the height for a comprehensive look, for looking around, for looking *down*. Or he attains it too late, when his best time and strength are spent—or impaired, coarsened, degenerated, so that his overall value judgment does not mean much anymore. It may be precisely the sensitivity of his intellectual conscience that leads him to delay somewhere along the way and to be late: he is afraid of the seduction to become a dilettante...' (Nietzsche 2003).

These words were written in 1886. The difficulties he described have now grown by orders of magnitude. Of course, Nietzsche was not speaking of people with PhDs in philosophy, but rather any and all who seek the 'height for a comprehensive look'. Philosophers in the 20th century have not been different from any other type of academic: they too reacted to the challenges posed by academic hyperproduction by applying Adam Smith's division of labour to their work.

Rather than an interdisciplinary method, what is needed is something more akin to a philosophy of interdisciplinarity, whether authored by philosophers, or not. For the current state of knowledge production raises fundamental questions concerning the purpose and functioning of knowledge in contemporary society. Among its central questions, is it possible to make a reasonable distinction between productive generalizations that may not get all their details correct, and dilettantism? How does the increasingly interdisciplinary nature of research affect the evaluation of knowledge claims, for instance through the process of peer review? A full accounting of these questions would require a second essay, but these questions can at least be approached via one of the most interdisciplinary of research projects today, the field of sustainability science.

KNOWLEDGE ON SUSTAINABILITY, AND MAKING KNOWLEDGE SUSTAINABLE

In what has become the canonical definition, the 1987 Brundtland Commission defined sustainability as development that 'meets the needs of the present without compromising the ability of future generations to meet their own needs'. More recently, the Sustainability Science Program at Harvard University's Center for International Development (CID) defined the goals of sustainability science as advancing 'basic understanding of the dynamics of human-environment systems; to facilitate the design, implementation, and evaluation of practical interventions that promote sustainability in particular places and contexts; and to improve linkages between relevant research and innovation communities on the one hand, and relevant policy and management communities on the other' (CID 2010)

Sustainability science is described today as an interdisciplinary field concerned with the behaviour and responses of the nature-society system, and the (often irreversible) response to perturbations of that system. The scope of its work is quite ambitious. According to Kates *et al.* (2001), 'Sustainability science will need to do the following: (i) span the range of spatial scales between such diverse phenomena as economic globalization and local farming practices, (ii) account for both the temporal inertia and urgency of processes like ozone depletion, (iii) deal with functional complexity such as is evident in recent analyses of environmental degradation resulting from multiple stresses; and (iv) recognize the wide range of outlooks regarding what makes knowledge usable within both science and society'.

The audaciousness of this project is reflected by the fact that this article in *Science* is co-authored by 23 researchers. The herculean labours of this article, and the field itself, are worthy of respect, but they also raise troubling questions. What happens when the concept of sustainability is applied to sustainability science itself, and by extension to the entirety of the increasingly complex contemporary intellectual enterprise? Is such knowledge production sustainable?

As noted above, knowledge production faces a combined set of economic, political and technological challenges. Any of these might place limits on knowledge production. But these may be matched or even exceeded by a set of social and epistemological dilemmas internal to academic research. Consider the perplexities faced by Kates *et al.* (2001). By the standards of normal (i.e. disciplinary) peer review, each of the 23 authors is unable to evaluate the contributions of the others. Moreover, each researcher individually, and all together, produces work that policy makers and the public are incapable of adequately evaluating. (In fact, it is questionable whether such complexity can ever be more than multidisciplinary in nature, true integration being impossible.)

Of course, the article was published in *Science*, and thus did make it through what is imagined to be the most rigorous process of peer review. And from outside standards, including both academics across a host of other fields and society at large, the article has been properly vetted. But who would *Science* get to properly evaluate such a production? Is it possible for *Science* to have adhered to its own standards of peer review here? And if not, what does this say about the long-term stability of the peer review process, either epistemologically or politically?

Epistemic productions are now so complex as to stymie traditional modes of scholarly evaluation such as peer review. In response, the research community has turned this problem into its own set of research projects, for instance through bibliometrics (the *h*-index and the Web of Science database) and the science of team science. The science of team science (SciTS) is a fast-growing field that seeks to master this complexity through an examination of the processes by which scientific teams organize, communicate and conduct research. The field is concerned with understanding and managing circumstances that facilitate or hinder the effectiveness of large-scale collaborative research, training and translational initiatives (NUCATS [Northwestern University Clinical and Translational Sciences Institute] 2010).

Now the subject of an annual conference and its own peer reviewed literature, SciTS seeks to develop 'tools, references, and resources' for managing the complexity of knowledge. SciTS functions as a de facto philosophy of interdisciplinarity, as well as a philosophy of peer review, but one that seeks to treat the problem through the development of 'tools, references, and resources'. Such efforts are likely to achieve some measure of success. But such efforts are also caught in a dilemma. Each increase in the complexity of accounts of phenomena, most outstandingly, the social-ecological system that is the subject of sustainability science, reduces the possibilities for democratic deliberation. Moreover, each increase in complexity makes the possibility of evaluation by experts harder, by introducing new variables, uncertainties and assumptions into the epistemological process. The system becomes ever more resistant to comprehension. The claim that it is possible to respond to these problems by increasing education levels misses the point: each increase in knowledge simultaneously increases ignorance by also increasing the number of assumptions and variables. Knowledge is caught in a double bind (Shattuck 1997).

This suggests that work on ecological sustainability (and research more generally) needs to be matched by consideration of a second parallel unsustainability, that of current modes of knowledge production. Knowledge production and consumption parallels material production and consumption, in that the former also has limits just as natural ecosystems have.

The dilemma facing knowledge production today was described at the beginning of the 19th century by the German philosopher Hegel. In the *Science of Logic*, Hegel warned of the dangers of a 'bad infinity' (Hegel 1969). He illustrated his point using mathematics. Mathematics displays two types of infinities, extensive, in that it is always possible to have $n + 1$, and intensive, in that there is always another number between any two numbers (Hegel 1969). For Hegel, what is bad about a bad infinity is that it has no end, in both senses of the word: no terminus and no goal. For Hegel, a good (or correct [*echt*]) infinity is one that is a self-contained totality, like a circle, the infinity symbol or a Mobius strip. Or perhaps most saliently, the Earth itself. Karl Marx picked up the concept of a bad infinity and applied it to the money form and to the structure of a capitalist economy. More pertinent here, cultural and ecological expressions of bad infinity can be seen in the endless and unsustainable growth of consumer desires.

The university suffers from another type of bad infinity, with knowledge production today exceeding all measure. In response, the academy (and its related branches, such as federal science agencies) is being forced to come to grips with this situation, as the funders of research demand a clearer accounting of the social outcomes of research. One sign of this is the growing pressure on the process of peer review, for instance in the US Federal Government's initiative called 'Expertnet', which is being created as a means for eliciting public participation in federal management policy (Open Government Initiative 2011). Public science institutions worldwide are struggling with evaluating complex projects, integrating societal concerns within the peer review process (Holbrook 2010). One sign of these difficulties this raises is the increasingly politicized nature of scientific results, most obviously perhaps in the climate change debate (Oreskes & Conway 2010).

Can there be such a thing as too much knowledge? Should academic institutions and the 'knowledge society' be reshaped, in recognition of the fact that there is an Aristotelian mean to knowledge? How can knowledge institutions be restructured in order to place proper limits to knowledge production? And how would this affect the political status of knowledge?

I do not pretend to have answers to these questions, but it is time to ask them. If there is one thing that fractious intellectuals have agreed upon, it is that more knowledge is invariably a good thing. Consider the outraged response that followed a suggestion in 2000 that, given the dangers of modern technoscience, relinquishment might be the only option (Joy 2000). While the question was not taken seriously at the time, it may no longer be possible to avoid the question.

The age of disciplinary knowledge may be ending, but the true shape of interdisciplinarity, and the essential characteristics of sustainability, are as yet unknown. To refer again to Hegel, the need to make both the subjective and objective poles of knowledge sustainable may be required, both knowledge about natural-social systems, and systems of thought. How can universities move toward a steady state epistemology? Would knowledge lose its power to persuade? Is it possible to map out a theoretical space between being lost in specialized expertise and mere learned generalities, and to fashion a workable account of how much knowledge is enough?

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