Can Policy Actors Learn from Academic Scientists?

Pre-publication draft submitted to Environmental Politics, February 2015.

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Abstract

Results from an embedded survey experiment administered to practitioners who advise landowners on decontamination practices are analyzed. These professionals play a key role in the area of soil decontamination, an issue that science has made particularly tractable and which calls for new technologies and policy approaches. Powerful interests, however, work against the rapid deployment of these new technologies and approaches. Our survey experiment, designed to overcome major difficulties in the study of policy learning, shows that exposure to new scientific knowledge can positively influence the attitude of practitioners to new technologies, independently of other confounding forces. This finding suggests that learning from science provides a potential pathway toward increased use of environmentally beneficial soil decontamination methods. Our results contribute to research on the politics of environmental protection, as well the literature on policy learning.

Keywords: Policy Learning; Science and Politics; Soil Decontamination; Phytoremediation; Survey Experiment.

Introduction

Some environmental problems are tractable. Scientists have a clear understanding of their causes, as well as of their consequences, and as a result solutions are relatively easy to conceive. Nevertheless, several of these tractable problems are insufficiently addressed, either by governments or by individual citizens. One example is the problem of environmental contamination. Scientists have identified hundreds of thousands of contaminated sites, and suspect that unacceptable levels of pollution are very likely in thousands more (Panagos et al. 2013). The different sources of toxins are well understood by scientists, as are the processes that lead to the dispersion of toxins throughout the environment and the associated risks to human, plant and animal life. In response, scientists have developed a variety of techniques for successful remediation. Yet despite the well developed scientific understanding of the problem and the availability of effective solutions, the vast majority of affected sites are left contaminated.

Observers conveniently hold politics responsible for the neglect of tractable environmental problems (e.g. Bradley 2011). Politics here is understood as the capacity of powerful actors to prevent governments or individuals from doing what scientific evidence would otherwise compel them to do. Political scientists have produced a wealth of studies demonstrating that change (or lack of it) depends on power relations, that is, on the distribution of capacities among actors to impose sanctions or provide spoils to others. Since the pioneering work of Hugh Heclo (1974), however, political scientists have paid increased attention to learning, an alternative process whereby change can also occur. The suggestion that policy change can occur through learning, not just powering, is an important one. It opens up the possibility of softer political processes that do not feature sanctions or spoils, which sometimes violate democratic ideals. More importantly, it suggests that science itself, without help from powerful actors, can provoke policy change.

Policy learning as a mechanism for policy change is an essential process for the development of environmental protection. Indeed, movement toward environmental protection is often characterized as an uphill battle against powerful forces that usually benefit from the status quo. Despite the significance of learning for environmental politics, however, the study of learning is fraught with significant methodological difficulties. Indeed, existing studies of policy learning often rely on crude ways of operationalizing the central variable of interest, "learning." Moreover, in the context of empirical work, commonly used process-tracing qualitative methods often fail to provide a degree of control that is sufficient for the empirical demonstration that learning actually takes place. These problems are significant as the burden of proof largely rests on scholars of learning, given the wealth of evidence demonstrating that power relations are determinant. As a result, despite years of learning scholarship, we still have a poor understanding of the extent to which learning matters.

Here, we develop a precise measure of learning. We use the case of a tractable environmental problem – soil contamination – as a crucial test of whether learning actually occurs. To overcome methodological difficulties, we administered an embedded survey experiment to key policy actors in the area of soil rehabilitation, and seek to determine whether actors with a substantial policy role are able to learn. While individual opinion change is only one step in a broader policy learning process that also involves a change in policy, we suggest that individual learning is a prerequisite for learning at the system level. Indeed, while individuals who learn cannot be expected always to work toward changing their policy environment, policy changes that are imposed on individuals responsible for their implementation are always at risk of failure (Pressman and Wildavsky 1973). In other words, individual learning can facilitate collective action.

Our survey experiment shows that when exposed to academic scientific research, practitioners on the ground learn, at least modestly. Given the role played by practitioners in proposing and evaluating decontamination practices, our findings suggest that incremental changes in opinion may provide, over the medium and long term, one potential pathway to broader policy change. Such a change in opinion may eventually produce a policy context in which it is easier to apply novel decontamination methods and in which fewer contaminated sites are left untreated.

The article is organized in four sections. First, we review the literature on learning and identify methodological problems that our survey experiment was designed to overcome. Second, we provide some context around the use of specific breeds of plants in decontamination and its relevance for testing whether important policy actors learn. Third, we provide details of our methods and protocol. Fourth, we discuss results, identify policy implications and conclude that experts can learn from academic science, despite the presence of forces that can make learning a non-trivial exercise.

Difficulties in the Study of Learning

Policy learning can be conceived as a two-level process in which learning can take place at the individual and system levels. Just as individuals may learn (or fail to learn) so too may organizations and institutions (systems). Learning, however, does not always occur in this order. Occasionally, organizations and institutions decide to promote new approaches and only later will their members come to accept these changes as improvements compared with the *status quo* (Moyson 2014; Lehtonen 2007). Of course, learning can also begin with individuals. Individuals can learn and those who learn will often, but not always, make an effort to align their organizational or institutional setting with the knowledge that they now consider valid. The conventional understanding of policy learning has encompassed both types of learning, without attributing too much importance to this distinction (Heclo 1974; Hall 1993). For the purpose of empirical study, we find the distinction between individual and system-level learning useful. Here we use it to delimit our scope to individual-level learning. Exposure to new scientific information provides one mechanism through which individuals learn, and this learning can provide useful insight into the capacity of systems to learn.

Beyond this issue of delimitation, the study of policy learning raises further challenges related to conceptualization. For instance, most scholars assume that learning involves change (Bennett and Howlett 1992), which may be observed in opinions, intentions (Sabatier and Zafonte 2001) and in policy (Hysing and Olsson 2008). Yet, as documented in studies of educational science (Illeris 2009), learning may instead reinforce one's prior beliefs (Leach et al. 2014). Despite this nuance being recognized in the literature, most studies of learning remain focused on change, displaying little care in operationalization to distinguish between learning as a significant change in opinions from learning as a less demanding reinforcement of prior opinions (Freeman 2006; Heikkila and Gerlak 2013). Here, we define learning as the acquisition and acceptance of new knowledge, followed by a review of prior opinions. Our research design enables us to distinguish a significant change from a reinforcement of previously held beliefs.

A focus on change in the literature leads to additional problems of inference. Indeed, change may take place in the absence of learning. For instance, some studies of learning accept as a premise that powerful actors institutionalize their policy advantages, making the *status quo* particularly sticky (Pierson 1993). Logically then, any observation of policy change can be taken as evidence that learning can overcome power. Yet, change can occur without any learning actually taking place (Radaelli 2009; Leach et al. 2014). Newly acquired knowledge may be used to justify a policy change, giving the impression of learning, while in fact camouflaging the emergence of powerful forces. In such contexts, some individuals act opportunistically, adapting their discourses to circumstances, which may give the impression that they learn. Some may be too afraid to admit that their changing discourse results from coercion by superiors or by powerful groups, attributing it instead to more benign learning processes. To the extent that studies fail to control for all potentially confounding factors, scholars identifying learning as change in the context of observational studies always run the risk of detecting learning processes when something else is going on.

In contrast, our experimental design allows us to operationalize learning as change without encountering the methodological problems commonly found in observational studies (McDermott 2002). Our pretest-posttest experimental design ensures that any observed change in participants' opinion is in fact due to exposure to new scientific research. In other words, our experimental design makes change a valid and reliable indicator of learning. Our study focuses on the extent to which practitioners change their opinion on decontamination practices after being exposed to new information about a biological treatment method known as phytoremediation. Exposure to this new scientific knowledge, we hypothesize, should increase acceptability of this new technology, especially among those who were skeptical at the outset. This focus on hypothesis testing is rare in studies of learning (Radaelli 2009) and represents, to our knowledge, the first experimental study of learning in the literature. While we recognize the contribution of studies employing process-tracing to the study of learning, our experimental design is better suited for making inferences on whether and the extent to which policy relevant actors are able to learn from new scientific research.

Learning from Decontamination Science

To better to contextualize our research effort, we provide key characteristics associated with the substantive problem of soil contamination and the promise of phytoremediation as a solution. We focus on three elements: the extent to which science has made the problem of soil decontamination tractable; the extent to which powerful forces make learning in this domain non-trivial; and, the extent to which our research participants represent important policy actors in the area of soil rehabilitation.

Problem Tractability

In a recent review, Dunlop and Radaelli (2013, 602) suggest that, for learning scholars, studying tractable problems is of less interest than the study of intractable ones. They argue that knowledge about tractable problems serves the lower purpose of "legitimizing" positions rather than the higher purpose of "educating". We instead adopt the view that tractable problems, just as intractable ones, encourage a non-trivial review of prior opinions. We also argue, from a methods standpoint, that studies of learning should begin with problems over which uncertainty does not loom too large. In fact, the more certain new knowledge is, the easier it is to make the case that a policy actor was genuinely "educated," as opposed to using knowledge in a self-serving manner (Leach et al. 2014). In other words, tractable problems provide easy (but non-trivial) cases; failure to observe learning in these cases makes failure to observe learning over intractable problems highly probable. Therefore, tractable problems should have an important place in the study of policy learning.

In the area of environmental politics, soil contamination is a good example of a tractable problem. Indeed, the problem of soil contamination, its sources and its consequences, have been objects of serious scientific studies. For instance, we know that, in both economically advanced and less advanced countries, the number of sites polluted with industrial and municipal waste is significant. The number of known contaminated sites that present clear risks for humans, water ecosystems and other receptors is estimated today at 160000 in Europe alone (Panagos et al. 2013, 4). Moreover, we know that this figure is a gross underestimate, given that property and privacy rights interfere with efforts in several countries to produce precise inventories, and given the fact that current waste disposal practices and industrial activities keep the number of polluted sites growing. Using simulations, Panagos et al. (2013, 4) estimate unacceptable levels of pollution on as many as 1.47 million sites in Europe, in addition to the 160000 sites known to be contaminated. The EPA has similar estimates, suggesting that land contamination is no less significant in the United States.[1] While we do not have an exact figure, current reviews leave little doubt that large portions of land are currently contaminated beyond acceptable levels.

A wealth of knowledge also exists about the consequences of leaving contaminated sites unrestored. Contaminants from polluted sites can be dispersed throughout the environment via wind and water, reaching a variety of wildlife, aquifers and watercourses. A large number of contaminated sites are in urban areas, increasing the risk of contact between humans and contaminants. Some toxins originating from polluted sites even enter the food chain. Toxicologists have shown that the various forms of exposure to these contaminants are harmful to humans, with effects ranging from minor irritations to deadly illnesses, including several forms of cancer (Johnson and DeRosa 1997). In other words, the current state of knowledge not only provides alarming estimates of the quantity of unrestored contaminated sites, it also warns against serious environmental and health consequences.

Current knowledge of land contamination makes the problem so tractable that one may wonder why so many of the sites known for their pollution levels are left unrestored. Interestingly, the answer to this question is also well known among specialists of site rehabilitation. Many of these sites were once the property of private industries that have since ceased operation. To the extent that little was known about the toxicity of several industrial inputs and effluents in the past, establishing responsibility is a complicated task. Other known contaminated sites, currently owned privately, are in the hands of firms or individuals whose economic activity is in decline and who therefore simply cannot afford costly rehabilitation. In addition, a large quantity of contaminated sites is under the responsibility of governments (mostly local governments) that lack resources adequately to address the problem. These latter sites are former dumps, roads or mechanical maintenance sites that governments have contaminated themselves, when practices were less wary of contamination than they are today. Governments also have the responsibility for sites that they have seized from private owners incapable of meeting their tax obligations. The bill for rehabilitation, for both governments and private owners who often

[1] http://www.epa.gov/ncea/roe/docs/roe_final/roe_final_landchap4_46contam_land.pdf

are in difficult financial situations, explains why so many sites remain contaminated despite serious environmental and public health concerns (McIntyre 2003).

The prohibitive cost of decontamination is explained by the off-site treatment technology currently employed in site rehabilitation. Conventional rehabilitation methods frequently involve the excavation of the contaminated soil and its transportation to landfills designated to receive contaminants or to recognized treatment facilities. Landfill storage requires secluded sites where risks of contaminant migration are low. These sites are rare and frequently located in remote places. Treatment facilities are also relatively rare, requiring large investments and specialized personnel and equipment. In both cases, heavy equipment to excavate and transport large quantities of soil is required. Local governments, which frequently are responsible for a large number of contaminated sites, cannot always afford these costly conventional technologies.

Aware of this problem, academic scientists have been working for over twenty years on affordable solutions to contaminated soil. Phytoremediation, which uses plants to stabilize, extract or degrade contaminants from polluted sites, is one promising solution. Sometimes combined with micro-organisms and fungi, the most basic function of plants in phytoremediation processes is to stabilize soil to prevent the migration of contaminants into water and neighboring sites. The plant and its roots also stimulate microbial activities capable of degrading organic contaminants, which remain in the soil or are evaporated in the air in less or non-toxic forms. Plants can also store heavy metals and other trace contaminants in their tissues (roots, branches and leafs), which can be harvested at the end of the growing season and treated off-site. This process, known as phytoextraction, replaces the removal, storage or treatment of large quantities of soil with the much less onerous removal and treatment of roots, branches and leaves. Not only significantly more affordable than conventional rehabilitation technologies, phytoremediation has a particularly low environmental footprint.

We have searched the scientific literature on phytoremediation indexed in Thomson's Web of Science and found a proliferation of articles published on the topic since 1995 (Montpetit and Lachapelle 2014). Through a review of this literature, we identified limitations of phytoremediation, of which four are particularly significant:

- plants sometimes have difficulty growing in highly contaminated soil (Gupta, Huang, and Corpas 2013);
- the extraction efficiency of plants varies from one trace element to the next (Leung et al. 2013);
- the process of extracting contaminants with plants is long, especially in comparison with the immediacy of excavation (Batty and Dolan 2013);
- the roots of plants can fail to reach deep-seated contaminants (Cameselle, Chirakkara, and Reddy 2013).

Most of the authors of these works, however, put forth practical solutions to each of these problems. More importantly, all the works we examined agreed that phytoremediation works, albeit with various degrees of efficacy. Phytoremediation has been shown to work fast with organic contaminants on sites where concentrations are not too high, and it works at a slower and variable pace with heavy metals and other trace elements (Doyle 2008).

None of the reviewed articles showed unintended negative effects likely to make the problem worse were contaminated sites to be treated with phytoremediation rather than being left unrestored. In other words, phytoremediation has been the object of extensive scientific studies that leave little doubt that it offers a beneficial solution for sites on which the cost of conventional decontamination technologies is prohibitive.

Thus, science has made soil contamination a tractable problem. Despite some difficulties, science has produced valid estimates of the number of contaminated sites. Hydrologists have shown that contaminants travel and toxicologists have a good idea of the environmental and heath effects of several contaminants. We also know that sites are left abandoned because of the prohibitive costs of conventional decontamination technologies. In this context, scientists have identified the new, more affordable technology, of phytoremediation, which has been found to be an effective rehabilitation technology in particular conditions. This certainly is as good as science can be in making a problem tractable. Such tractability, however, does not turn learning into a trivial exercise. No matter how tractable the problem may be, exposure to new knowledge does not necessarily imply that individuals automatically accept the science and incorporate this new knowledge in their beliefs.

Tractable, but Politically Charged

Science, even academic science, rarely operates above politics (Ingold and Gschwend 2014; Montpetit 2011). Even experts can resist even the most indisputable knowledge, if this knowledge shows that their actual judgment is wrong (Tetlock 2005). Some policy actors have much to lose in accepting scientific knowledge, and they will therefore expend considerable resources to raise sufficient doubts to prolong debate (Lodge and Matus 2014). Several of the actors in the domain of soil contamination have interests in the use of conventional technologies and are therefore likely to resist initiatives to make the policy environment friendlier to phytoremediation.

Soil decontamination requires an expertise provided by recognized professionals who are likely to favor conventional technologies. Owners of contaminated sites will generally commission their decontamination projects to firms that employ these professionals, who have the knowledge and skills to evaluate contamination levels, prepare decontamination plans and oversee their implementation. The legal environment in which these professionals work has important implications for the advice they offer to their clients, be they private owners, municipalities or other governments. For example, the laws regulating soil rehabilitation frequently specify targets for specific contaminants that have to be met within specified timelines. These targets and timetables can disadvantage phytoremediation, which might come at a lower cost, but whose effectiveness at removing contaminants may take longer. To reduce future liability for the clients and occasionally to create favorable conditions to fund development projects on decontaminated sites, rehabilitation professionals might advise against phytoremediation. These professionals know from experience that the technologies to which they are accustomed have, numerous times and under various conditions, met existing legal standards. Scientific knowledge on a new technology such as phytoremediation can thus rub against the experience of decontamination professionals, depending on the legal environment in which they produce their advice.

Another source of resistance might be the whole industry that has developed over the years around conventional methods of soil rehabilitation. With large investments in the heavy equipment and specialized labor force specific to off-site storage or treatment methods, this decontamination industry might be reluctant to adopt a new technology that requires different equipment and skills. The firms owning the equipment sometimes directly employ soil decontamination professionals and sometimes these professionals work for engineering or environmental consulting firms. Even if the latter do not have their hands directly tied by investments in conventional technologies, the professionals that they employ work closely with the decontamination industry, fortifying their ties. Professionals in consulting firms might be expected to prefer working with the people they already know and who happen to have a preference for conventional decontamination technologies that employ heavy equipment. Scientists who work on the development of affordable technologies might be expected to face a serious challenge in convincing professionals to consider alternative decontamination technologies that requires building new networks of personal relations.

Science has produced a clear understanding of the problem of soil contamination and it has shown that phytoremediation offers a suitable solution. It is, however, unlikely that science makes the actors automatically update their preferences in a way that would make phytoremediation more acceptable. Powerful forces make the acceptance of this technology a politically charged issue. Despite problem tractability, learning is not a trivial process.

The Policy Relevance of Phytoremediation and of Professionals

The professionals who advise owners on how best to decontaminate sites also play a key policy-making role. In establishing norms regulating acceptable contamination levels and timetables to reach them, the legal environment influences choice of technology. At the same time, governments keep track of technological developments, and constantly try to align laws and regulations to the best available technology. Given their knowledge and experience, decontamination professionals play a key role in this process, making up for a lack of government's own capacity in this highly specialized domain. As is true for policy processes in general, the process is not straightforward and the biases of decontamination professionals in favor of or against given technologies are likely to distort it. Decontamination professionals' inclination to learn about new technologies from the latest scientific research thus has significant policy implications.

The debate surrounding appropriate remediation policy opposes two broad approaches—one that seeks to eliminate all risks and one that seeks the regulation and management of these risks. The first approach requires owners who want to undertake new activities on a contaminated site to reduce the presence of contaminants on the entire site below levels deemed safe for residential or industrial use. The imperative to practically eliminate contaminants within a short time frame provides a clear advantage to excavation and off-site treatment or storage. For reasons discussed above, powerful interests are likely to support this approach, although it has the known side effect of limiting the number of sites on which rehabilitation is undertaken. When this approach is dominant, the large numbers of contaminated sites of lesser economic value are frequently abandoned, given the cost of excavation and off-site treatment/storage.

The risk management approach offers more flexibility to site owners. Rather than risk elimination, the approach seeks to minimize risks according to specific usage. Under this approach, an owner could excavate part of a contaminated site on which human activity is planned and thus eliminate all health risks. Rather than transporting the contaminated soil to a remote location, however, the approach allows for its displacement onto an isolated part of the site where leaching risks are low and where phytoremediation could be applied to slowly eliminate the contaminants. Through this approach, risks are minimized rather than immediately eliminated, but its lower cost leaves owners, often governments, with resources to treat more sites. Decontamination professionals inclined to accept low cost technologies such as phytoremediation are also likely to favor the risk management rather than the risk elimination approach to policy.

The decontamination professionals we studied work in Quebec, Canada, in a legal environment promoting risk elimination. In fact, the province's environmental protection Act requires the decontamination of any site undergoing a change of use, including the simple termination of certain industrial activities. Under the Act, the soil on a site undergoing a change of use must be analyzed for the presence of regulated contaminants. If contaminants are found above specified thresholds, a decontamination plan must be put into place to bring the soil below the statutory norms. In this process, professionals accredited by the province's Ministry of the Environment certify that the initial characterization of the contaminated site, the implementation of the decontamination plan and its impact on contamination meet the standards specified in the Act. The accreditation confers upon these professionals significant credibility in the domain of decontamination. Their responsibilities under the law also encourage environmental consulting and engineering firms that offer services in soil decontamination to employ them. Not only are these professionals authorized to certify the decontamination of sites targeted by the Act and treated by the firm that employs them, but the accreditation also offers the employer a guarantee of competence and experience in soil decontamination. Therefore, accredited professionals generally occupy the highest ranks of the decontamination units of consulting and environmental services firms, and are an important resource for government officials. In total, the Quebec ministry of the environment has accredited 109 experts in site rehabilitation, spread across over 30 firms.

These 109 experts do not entirely satisfy the demand for decontamination professionals by consulting and environmental services firms. Therefore, these firms turn to a second group, the *Évaluateur environnemental de sites agréé* (EESA), to meet their needs for experienced experts in soil decontamination. The EESA is a professional accreditation delivered by the *Association Québécoise des Évaluateurs Environnementaux* (AQVE). Unlike the professionals accredited by the ministry, the EESA are not authorized to certify the decontamination of a site targeted by the environmental protection Act, but nothing prevents them from working on the preparation of plans to decontaminate these sites. Moreover, they can handle on their own, from beginning to end, the voluntary decontamination of the several sites that do not fall under the authority of the province's environmental protection act. Just like the ministry accreditation, the EESA offers employers a guarantee of qualification and experience in soil decontamination. There are currently 122 EESA in Quebec and unsurprisingly they occupy senior ranks in several consulting and environmental services firms and play a policy role among the professionals accredited by the government. In fact, 38 of these professionals hold both accreditations.

In short, scientific knowledge makes the problem of land contamination highly tractable, pointing toward phytoremediation as a solution. This solution, however, runs against powerful forces and the capacity of professionals to learn from scientific knowledge thus appears problematic. Moreover, technology acceptance in this domain intermingles with policy preferences for risk elimination and risk management. Given decontamination professionals' position in the entourage of policy-makers, we confidently assume that their acceptance of phytoremediation has policy implications: as they come to accept phytoremediation, they also become more likely to promote a legal environment more amenable to risk management.

Presentation of the Survey Experiment

In order to ascertain whether practitioners learn from scientific research, we devised an embedded survey experiment and administered it to all the soil decontamination professionals in the province of Quebec. Because 38 of them are both members of the EESA and accredited by the ministry, the total number of individuals targeted was 193. Of these, 94 (or 49%) filled out the survey entirely sometime between November 18 and December 12, 2013. Given the visual elements that it involved, the survey was web-based. Participants were asked conventional socio-economic questions, in addition to questions about their experience in soil decontamination and their environmental values. Notably, these questions make it possible to test whether the random selection of participants for the control and experimental groups yielded roughly equal sub-samples with balanced characteristics.[2] Such balance was particularly important here to control for factors potentially influencing learning, which is often lacking in studies of learning that employ observational methods.

As part of the survey, all participants were first asked to read about a contaminated site (Figure 1) and then to evaluate decontamination plans for this site, one of which specifically

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[2] Group balance was in fact tested and confirmed. The test consisted in running a logistic regression on the presence of participants in the experimental and the control groups on eight independent variables (the same variables as those used in Figure 6). Balance, or randomness, was confirmed by the failure of every single independent variable to predict the attribution of the participants to one group or the other. The regression coefficients and t statistics (in parenthesis) were as follow: women 0.255 (0.48) age -0.0273 (-0.91) experience 0.0277 (0.71) accreditation 0.470 (0.97) engineering -0.429 (-0.89) knowledge test -0.104 (-0.48) environmental values 0.0432 (0.24) acceptability of phyto 0.140 (0.95) constant 0.253 (0.14). N=90 and adj. R^2=0.03.

involved phytoremediation (Figure 2). To ensure that phytoremediation in this case was appropriate, the contaminated site and the description of the decontamination plan was loosely-based on real cases of successful site rehabilitation using phytoremediation (the cases were cited in Doyle 2008). In addition to making sure the site presented to participants was amenable to phytoremediation, we neutralized the effect of the legal environment, which sets strict decontamination thresholds. We did so by specifying that the decontamination was to be undertaken by a local government on a voluntary basis. Under such conditions, the environmental protection Act in Quebec does not apply.

[Insert figures 1 and 2 about here]

Later in the survey, the participants randomly assigned to the control group were simply asked to read once more the same description of the site and asked to assess the plan involving phytoremediation a second time. The participants in the experimental group also had to go through the evaluation a second time, but before doing so, they were invited to read the abstract of a 2010 article they were told had been published in *Nature* by a group of fictitious professors at MIT. The abstract, presented in Figure 3, was in fact adapted from a real article published in *Plant and Soil* (Bissonnette, St-Arnaud, and Labrecque 2010), which provides evidence that phytoremediation works. We attributed the article to MIT professors and claimed that it was published in *Nature* simply to highlight for participants the scientific importance of the article. During the post-survey debrief, participants were informed that they had been exposed to a manipulation and we provided them with the exact reference of the real article.

[Insert figure 3 about here]

In addition to the site description, which neutralized the legal environment in a case in which phytoremediation is feasible, the random assignment of the participants to a control and an experimental group provides for a high degree of control for confounding factors. In other words, the experimental design provides significant assurance that learning occurred if the acceptance of phytoremediation increases in the experimental group, while remaining stable in the control group. Here, a change in opinion in the experimental group provides a reliable and valid indicator of learning.

The Results of the Survey Experiment

Figure 4 plots the difference in the distribution of pretest and posttest attitudes toward phytoremediation for participants in the control group. A value of 3 on the horizontal axis in Figure 4 corresponds to the threshold between acceptability, on the right, and unacceptability, on the left. The Figure shows a small movement in the distribution of control group participants to the right between the pretest and posttest evaluations. At 2.8, the average acceptability for the control group in the first evaluation was below the acceptability cut-off point, but it reached 3.26 in the second evaluation. This difference between the two evaluations is significant in a pair-wise test of means with a 95 percent confidence interval (not reported here). Because the control group was not exposed to the abstract of the scientific article, we were not expecting a difference between their pretest and posttest evaluations. The small movement from unacceptability of phytoremediation to acceptability might have resulted from social desirability. In fact, by the time of the posttest, it may have become clear to participants that we were particularly interested in their attitude toward phytoremediation and as a consequence they might have adjusted their opinions accordingly. Moreover, several of the questions on phytoremediation to which participants were exposed between their two evaluations provided information on the technology, from which they might have learned.

[Insert Figure 4 about here]

Figure 5 shows that the difference in attitudes between the two evaluations for the experimental group is much larger than that in the control group. At 2.96, acceptability in the experimental group in the pretest evaluation is just under the cut-off point and, as expected, it is not statistically different from acceptability in the control group on the same question. After being exposed to the scientific article presented in Figure 4, however, acceptability in the experimental group reached 3.8, a score that is significantly higher, at a 95% level of confidence, than the score obtained in the control group. While 40% of participants in the control group improved their perception of phytoremediation, improvements were observed among 54% of the experimental group, a mean improvement in the control group of 0.55 (on a 0-6 scale), compared with 0.75 in the experimental group. Thus several participants who were skeptical at the outset had become generally favorable to phytoremediation toward the end of the survey, with participants in the experimental groups learning significantly more than the others.

[Insert Figure 5 about here]

To determine whether the change in opinions observed in the experimental group is attributable to exposure to the scientific article, we ran additional tests. Such control is essential if one is to build confidence in the claim that an observed change of opinions is attributable to learning. Participants were randomly assigned to the control group or the experimental group, whose aggregate characteristics are similar (see note 2). Moreover, any study-effect bias, notably social desirability, is unlikely to differ between the two groups. In other words, participants in the two groups were exposed to all the same conditions but one: new knowledge from the abstract of a scientific article presenting evidence that phytoremediation works. Logically therefore, the difference in attitudes between the control and experimental groups can only be attributed to exposure to the scientific article; the involvement of any form of powering, sanction or spoil, in the change of opinions can be ruled out.

Figure 6 presents the results of a logistic regression in which the dependent variable identifies all of the participants whose appreciation of phytoremediation has improved between the pretest and posttest evaluations. Figure 6 shows that belonging to the experimental group, that is, being exposed to scientific research, increases the probability of a change in opinions about phytoremediation among participants more than all other factors in the model. It is noteworthy that the degree of change between the pretest and posttest evaluations among those who displayed a high degree of acceptance at the outset of the questionnaire is lower than for those who initially displayed low acceptance. Those favorably predisposed to the technology might have been expected to move further along the acceptance scale as a result of exposure to research that confirms their prior beliefs, but we do not find that.[3]

Having strong environmental values, scoring high in a knowledge test on phytoremediation, having a university degree in engineering, holding an accreditation from the government, years of experience in soil rehabilitation, being younger or older and being a woman or a man do not significantly enhance the probability of an increase in the acceptability of phytoremediation among participants. According to Figure 6, acquiring knowledge of scientific evidence that phytoremediation works produces a positive change toward acceptability. Despite a variety of countervailing factors, experts can learn from science.

[Insert Figure 6 about here]

The difference between the control and experimental groups can be either viewed as disappointingly low or as surprisingly high. It might be viewed as low when the enviable reputations of *Nature* and of the MIT are taken into account. The more importance one grants to the credibility of the journal and of the scholarly institution, the larger the expected impact. In contrast, the difference might be viewed as surprisingly large to anyone who believes that it is premature to adjust one's perception of a technology from evidence provided by a single journal article. In fact, only the abstract of the article was presented to the participants in the experimental group, not the full article, making it impossible for the skeptical reader to scrutinize the study's methods and results. Regardless of which interpretation is preferred, we argue that, taken together, figures 4 and 5 provide evidence that experts can learn from science, albeit in small increments. In light of these results, we surmise that only the accumulation of scientific research over a period has the potential of changing the *status quo* significantly. Science might have the capacity to change policy without the application of sanctions and spoils (even against these powerful forces), but such a soft process can only be effective over the longer term.

Conclusion

In the area of decontamination, powerful forces work against the acceptance of phytoremediation by professionals. These professionals sometimes work for firms that belong to an industry that has large investments in conventional technologies; sometimes they work for consulting firms that have close ties with this industry. These technologies are expensive and therefore the forces working against phytoremediation significantly reduce collective capacities to face the challenge of rehabilitating the thousands of contaminated sites that exist today around the world and which present clear environmental and public health risks, unless, of course, the dissemination of new scientific

[3] To ascertain this finding, we included an interactive term to verify whether respondents in the experimental group who were more accepting of phytoremediation at the outset were also more likely to learn. The term was statistically insignificant.

discoveries can convince decontamination professionals that widely deploying less expensive, alternative technologies is worthwhile.

Here, we have shown empirically that professionals can learn from academic scientists. In the experiment we conducted, no sanction or spoil was necessary to make professionals more accepting of phytoremediation. Exposure to academic scientific research sufficed to change the opinion of professionals on this technology, albeit only modestly. Through the experiment, we nevertheless showed that learning can even counter powerful forces that favor the *status quo*. This finding makes a significant contribution to environmental politics, an area in which the interests of the powerful are not always amenable to environmental protection. There is hope that scientific discoveries will be taken up by potential users despite initial resistance. There is also hope that academic science will accelerate the pace and widen the scope of site decontamination against economic interests that push in the other direction.

It should be underlined that we have examined a single aspect of policy learning: individual learning. We have left to future research the task of looking at the extent to which the participants of our experiment, who are key policy actors, successfully translate their learning into policy. We nevertheless conjecture that greater acceptance of phytoremediation has significant policy implications. To the extent that the dominant policy framework in the context of Quebec (and to a large extent, North America) is one of risk elimination, current decontamination practice privileges excavation and treatment offsite. In this policy environment, movement toward treatment onsite with the use of phytoremediation reflects a distinctive policy approach in which risks are instead managed. Moreover, in addition to favorably predisposing key policy actors in the field of soil decontamination toward a risk management approach, such learning might also facilitate cooperation in places where a risk management approach is imposed by force. The impact of system-level change is less likely to end in failure when it is accompanied by individual learning.

Experiments involving elites are rare. Experiments in social science often use students or members of the general public as research participants, and their external validity is frequently questioned (Barabas and Jerit 2010; Henrich, Heine, and Norenzayan 2010). Indeed, the conditions of the experiment sometimes appear so artificial that they risk having little to do with reality. In contrast, the experiment presented here asked real professionals to do what they do on a daily basis: assess decontamination plans for given sites. In subsequent discussions, we presented our results to the decontamination professionals who participated in our study, and validated our results. Nevertheless, we also learned that many professionals rely on professional conferences and professional publications as a source of information, while only a handful regularly read peer-reviewed journals where the latest scientific research is found. If not encouraged to do so, professionals are unlikely to read the type of peer-reviewed journals from which the abstract in our experiment was taken. In other words, scientists might have to make the extra effort of contributing to professional conferences and journals if they want those in charge of applying technological solutions to learn from them.

Acknowledgements

The authors acknowledge the financial support of Genome Quebec and Genome Canada. They also thank the members of Genorem for their contribution to this research, as well as Monika Smaz and Irena Nedeva for excellent research assistance. They also thank André Blais and Alexandre Morin-Chassé for useful comments on a previous version.

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Figure 1: Description of a Contaminated Site

Located in the periphery of a large city, this building-free 2.7 hectare site has been abandoned by its owner. It is zoned industrial and commercial. In the 1980s and the 1990s, a wood treatment facility operated on the site, where creosote, copper, zinc, lead, chrome VI and arsenic was used. The soil is sandy silt and the contaminants are at less than a meter deep. The contamination is generally in the B-C zones of the criteria of the province's policy, but they occasionally reach above the C level. Based on documents and a site visit, it was decided that underground water contamination was a risk. Abandoned several years ago, the site was seized by the municipality that now wants it rehabilitated, although it has no specific project for it.

Figure 2: Presentation of a Rehabilitation Scenario

Trees with roots deep enough to reach underground water will stabilize contaminants, preventing leaching. Among the species authorized by the municipality, hybrid willows and poplars will form a barrier limiting the dispersion plume. The contaminants will thus be attracted to the root area and immobilized. The microbial activities in this root area will degrade the organic contaminants. Some of these contaminants will also be evaporated in the atmosphere by the plants. Inorganic contaminants will be removed from the soil by the trees, which will accumulate them in their tissues and be treated off-site after their harvesting.

In your opinion this rehabilitation scenario is:

0. Completely unacceptable
1. Unacceptable
2. Moderately unacceptable
3. Neither acceptable nor unacceptable
4. Moderately acceptable
5. Acceptable
6. Completely acceptable

Figure 3: Presentation of the Abstract of a Scientific Article

Please read the following abstract of a scientific article on phytoremediation, published in *Nature* in 2010. [After having read the abstract, participants were invited to read once again the site description presented in Figure 2 and to evaluate once again the rehabilitation scenario presented in Figure 3].

Phytoextraction of heavy metals by two Salicaceae clones during the second year of a field trial

Lou Atkinson, William Duran & Michael Pauly (MIT)

Abstract : We evaluated the potential of two willow species, S. viminalis and P. Å~ generosa, for the phytoextraction of heavy metals (HM) during a second year of growth in a randomized complete block field trial on a slightly contaminated site. Both plant clones produced high aboveground biomass yields, however P. Å~ generosa produced significantly more biomass than S. viminalis. The two plant clones accumulated high concentrations of cadmium (Cd) and zinc (Zn) in their shoots, while copper (Cu) and lead (Pb) were stored in their roots. In general, S. viminalis accumulated higher concentrations of HM. Efficiency of S. viminalis and P. Å~ generosa for Cd and Zn rehabilitation in slightly contaminated soil has been demonstrated. S. viminalis proved more efficient than P. Å~ generosa for Cu and Pb.

Figure 4: First and Second Evaluations of Acceptability in the Control Group

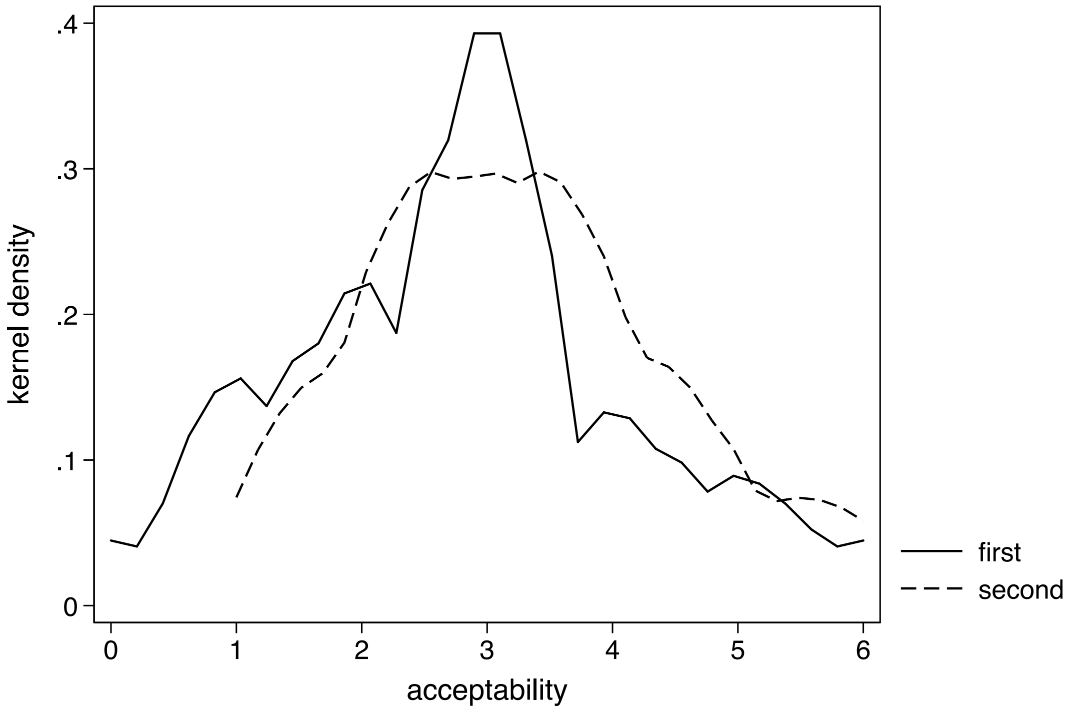

Figure 5: First and Second Evaluations of Acceptability in the Experimental Group

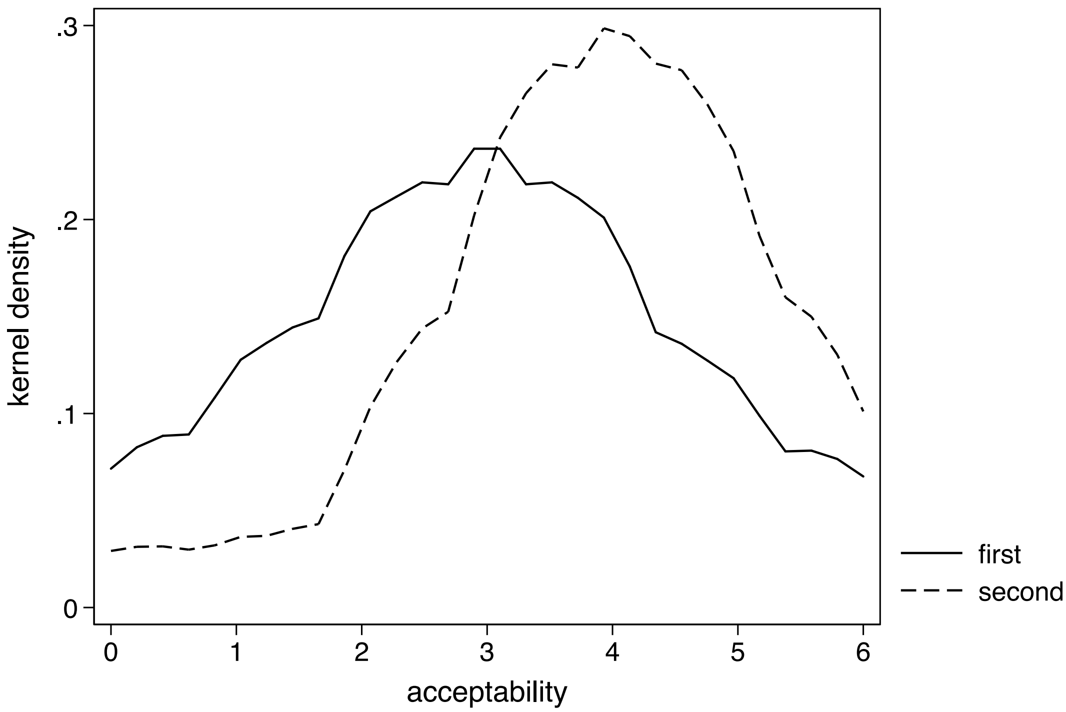

Figure 6: Marginal Effects on the Probability of a Change in Opinions