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# **The Mercury Game: Evaluating a negotiation simulation that teaches students about science-policy interactions**

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## **The Mercury Game: Evaluating a negotiation simulation that teaches students about science-policy interactions**

**Abstract:** Environmental negotiations and policy decisions take place at the science policy interface. While this is well-known in academic literature, it is often difficult to convey how science and policy interact to students in environmental studies and sciences courses. We argue that negotiation simulations, as an experiential learning tool, are one effective way to teach students about how science and policy interact in decision-making. We developed a negotiation simulation, called the Mercury Game, based on the global mercury treaty negotiations. To evaluate the game, we conducted surveys before and after the game was played in university classrooms across North America. For science students, the simulation communicates how politics and economics affect environmental negotiations. For environmental studies and policy students, the mercury simulation demonstrates how scientific uncertainty can affect decision-making. Using the mercury game as an education tool allows students to learn about complex interactions between science and society and develop communication skills.

### **Keywords**

Science education; Environmental curriculum; International negotiations; Science-policy interface; Mercury policy

### **Introduction**

Environmental negotiations and decision-making take place at the science policy interface. Although scientific certainty has increased on biodiversity loss, ozone depletion, climate change, and hazardous chemicals, effectively integrating this scientific knowledge into the policy process remains a major challenge for all environmental treaty negotiations. Strategies for incorporating scientific information into negotiations include developing scientific assessments, setting up subsidiary science bodies, appointing scientists to leadership positions in international organizations, and ensuring social and economic dimensions are integrated with science (Bernstein 2002; Najam et al. 2004; Mitchell et al. 2006; Kohler 2006). Non-governmental organizations (NGOs) are also key purveyors and framers of scientific information in environmental negotiations (Susskind 1994; Betsill and Corell 2001; Betsill and Corell 2008).

While the complex role science plays in international negotiations and decision-making is clearly demonstrated in academic research (Jasanoff 1994; Susskind 1994; Mitchell et al. 2006; Pielke Jr. 2007), this idea can be difficult to convey to students within a classroom setting. Yet, this is a critical learning objective. Jasanoff (1994) argues that scientists attempt to maintain their authority and create a space for productive work on key societal questions through "boundary work"—defining what is within and outside the domain of scientific authority. At the same time, these boundaries that attempt to delineate scientific authority, are constructed by people, and as a result, can be contested. Science and society must seek a balance between

strong boundaries between scientists and policymakers, allowing for scientific integrity, and permeability, allowing scientific information to be useful and informed by public needs (Clark et al. 2010). Further, Susskind argues that scientists need to ensure they do not become “just another interest group” whose findings can be dismissed, and ensure their technical advice is politically savvy (Susskind 1994). When students enter careers in environmental policy, they will be faced with these challenges at the science-policy interface. As educators, how can we prepare students, building their skills to communicate under scientific uncertainty?

Teaching across traditional disciplinary boundaries can be particularly important for environmental education (Ehrlich 2011). However, in practice it is difficult to accomplish, given students’ varied training and experiences. Environmental studies and science courses at the post-secondary level typically include students with diverse backgrounds (McMillan et al. 2004). For science, engineering and public health students, a science-policy class may be an opportunity to learn about negotiations and policy, including the role economics and politics play in the policy process. For environmental studies students from interdisciplinary programs, social sciences, public policy, and the arts and humanities, these courses provide a window into the scientific constraints on environmental policy. Science-policy courses reach students with a wide variety of future career goals. Although many students may go on to careers in research, others may end up working in policy.

Negotiation simulations are one, effective solution to bring science and engineering students into conversation with social science and policy students. Often called negotiation games, these simulations establish a specific context and problem that several players attempt to solve collaboratively. Confidential instructions, which each player reads in advance, create a rich policy setting that participants explore through discussion. Through adopting a role, students are challenged to actively reinterpret information (Aubusson et al. 1997). In this way, the game creates an experiential learning environment where students can learn both content and process-based knowledge (Susskind and Corburn 2000; McLaughlin et al. 2002; Makinster 2010). This kind of immersive learning can make concepts more meaningful and relevant (Gordon et al. 2011). Simulations have long been used to teach policy students about negotiation dynamics (Susskind and Corburn 2000), and more recently employed in science education (Aubusson et al. 1997; Simonneaux 2001; Makinster 2010) and political science classrooms (Asal and Blake 2006).

Several science-policy simulations exist, including one on genetic modification discussions in a US Senate committee (Makinster 2010), another on the international climate negotiations (Sterman 2011) and a third on global chemicals regulation (Najam 2001). However, while these simulations touch on scientific evidence, they do not present students with a model of how science is digested, interpreted or represented in policymaking and negotiations. To fill this gap, we wrote the Mercury Game, a negotiation simulation based on the United Nations Environment Programme (UNEP) global mercury negotiations. Although these negotiations concluded with the Minamata Convention in 2013, we placed the game

earlier in time, focusing on the period between 2003 and 2009 when decision-makers considered the scientific question of whether mercury posed a significant global threat. The game uses a scientific assessment to guide discussions. To our knowledge, the Mercury Game is the first simulation that brings environmental science and studies students into one conversation, using scientific information as the focal point. The game provides a realistic and meaningful social context in which scientific decision-making occurs, and helps students grapple with the limits of scientific information – a key challenge when teaching science literacy (Feinstein 2011).

As a science-policy simulation, the mercury game has three major learning goals: it aims to teach students (1) substantive, (2) process-based and (3) communication knowledge. First, students should gain substantive knowledge about an environmental problem: global mercury pollution. Second, they should learn process-based knowledge about the interactions between science and policy. Practice, interaction and experience-based learning are essential for student learning about abstract science and policy concepts (Handelsman et al. 2004). Through experience, students develop and refine their mental model of how a policy process can use, interpret and even misrepresent science. Science students in particular need academic curriculum that helps them develop a better understanding of how science interacts with society, within a policy and problem context (Kates et al. 2001). As science education research has argued, broad, analytic skills are important in addition to content knowledge in science classes, and these skills likely appeal to a diverse range of students (Anderson et al. 2011).

Third, the game aims to teach science and policy students about the important role communication and translation play when science is used in policymaking and negotiation. Scientists often communicate in a way that is confusing to the public (Weber and Word 2001; Somerville and Hassol 2011). Communication training can help students think about how they can create compelling narratives and frames, focused on what *is* known and the causes. This style of communication can speak to non-scientists. As scientists are increasingly addressing issues of public concern, science communication training is becoming critical (Besley and Tanner 2011). Research suggests the majority of scientists consistently engage with media (Peters et al. 2008), and students need to be prepared for this role in their future careers. Together, these three learning goals make the mercury game a useful addition to a broad range of environmental science and studies courses.

This paper begins by explaining how the mercury game and the evaluation surveys were constructed. Next, it presents the results from the pre and post game surveys, showing the key differences we uncovered between science and social science students. Survey results from our evaluation of the mercury game suggest that students indeed learn process based knowledge about the complex interactions between science and policy from playing the game, while also gleaning factual knowledge on mercury's environmental impacts and improving their communication skills. We conclude with a broader discussion of how negotiation

simulations can be used in environmental science and studies classrooms to promote learning about the science-policy interface.

### **Methods: The Mercury Game**

The Mercury Game is a role-play simulation designed for students, although it has also been played with scientists and negotiators in the United Nations Environment Programme (UNEP) mercury negotiations. The game is based on UNEP's international negotiations between 2003 and 2009, which attempted to formulate a global response to mercury pollution. In this period, policymakers discussed the question of whether there was adequate scientific information about mercury's risks to humans and the environment. In the mercury game, players collectively address this question over the course of three hours, by interpreting a scientific assessment and discussing it together. The game concludes with a debriefing that discusses how policymakers consider science during negotiations and the importance of scientific communication.

Mercury was chosen as the game's issue area for several reasons. First, with the recently concluded Minamata Convention on Mercury, the first environmental treaty in over a decade, the game is timely (Selin 2014). This allows students to learn about an evolving area of global environmental regulation and a current scientific issue. Second, students are unlikely to have significant knowledge about mercury to begin with, allowing us to evaluate their learning through playing the game more readily. In addition, students are unlikely to have a pre-existing position on the issue, particularly compared with higher profile issues such as climate change. Third, while mercury is both timely and lesser known as an issue area, it also highlights similar dynamics to other environmental negotiations, such as conflicts between developed and developing countries over rights and responsibilities. In this way, learning about mercury as a specific environmental negotiation also allows students to gain insights into broader challenges and opportunities in international environmental negotiations more broadly.

While the main question for participants is whether mercury is a global pollutant requiring global attention, the players are also asked to address specific issues regarding the possible form and scope of global cooperation (see Table 1). These issues were chosen to illustrate important science-policy dynamics applicable to a wide range of international environmental issues. Specifically, the authors attended several rounds of the UNEP negotiations to gain an understanding of the main issues and countries' positions on these issues. This participant observation was supplemented by reviewing primary sources from the negotiations, including countries' submissions to the process and UNEP mercury reports. We then created a matrix of the roles and issues, to see whether the game would create a zone of possible agreement for the game players.

### **Table 1. Issues and Options in the Mercury Game**

Issue and Question	Negotiation Options
<p>1. The form of future action</p> <p>Is global action necessary to address mercury, and what form should it take?</p>	<p>1.1: There is sufficient evidence that mercury is a global problem with significant risks. Initiate formal international negotiations for a new legally binding mercury convention.</p> <p>1.2: There is a need for more evidence that mercury is a global problem with significant risks. Enhance voluntary measures.</p>
<p>2. Atmospheric emissions</p> <p>Should atmospheric emissions of mercury be included within the scope of a potential agreement?</p>	<p>2.1: There is sufficient information that atmospheric emissions are a large source of mercury. This issue should be included in the scope. Future negotiations could include requiring national emissions inventories and proposed timetables and targets for all major emitters.</p> <p>2.2: There is insufficient information that atmospheric emissions are a large source of mercury. This issue should be excluded from the scope. Future negotiations could gather information on emissions inventories to all media before taking action.</p>
<p>3. Products and processes</p> <p>Should global demand for products and processes be included within the scope of a potential agreement?</p>	<p>3.1: There is sufficient evidence that demand for mercury used in products and processes significantly contributes to the global mercury problem. All products and processes should be included in the scope of future negotiations.</p> <p>3.2: Demand for mercury used in some products and processes contributes significantly to emissions and mercury releases, while other mercury uses do not. The parties should draft a list for inclusion in the scope of future negotiations.</p> <p>3.3: There is insufficient evidence that demand for mercury used in products and processes significantly contributes to the global mercury problem. All products and processes should be excluded from the scope of future negotiations.</p>
<p>4. Artisanal and Small-scale Gold Mining (ASGM)</p> <p>Should mercury emissions from ASGM be included within the scope of a potential agreement?</p>	<p>4.1: There is sufficient evidence that mercury use in ASGM is a significant part of the global mercury problem. ASGM should be <i>included</i> within the scope of future negotiations, with potential actions including requiring countries to submit national action plans on ASGM with timetables to phase out the usage.</p> <p>4.2: There is insufficient evidence that mercury use in ASGM is a significant part of the global mercury problem or that ASGM is a tractable problem. ASGM should be <i>excluded</i> from the scope of future negotiations while financial and technical support are provided to conduct further assessments on ASGM.</p>

A scientific assessment, “The International Mercury Assessment”, is the game’s centerpiece, making this tool different than most simulations designed for negotiation courses. The 20-page assessment, modeled after scientific summaries used in environmental negotiations, digests the science in a way that allows players

to use and question it during the game. As a result, scientific uncertainty, risk and information gaps become principal issues for discussion. The assessment is based on peer-reviewed science, so while students focus on the negotiation process, they also learn substantive knowledge about mercury science.

The game requires each player to take on the role of a specific country representative or an NGO, and read their role’s confidential briefing instructions before playing the game (Table 2). Instructors were told, through the teaching note, to assign students comfortable speaking in front of the class roles of greater prominence in the negotiations, such as the United States, the EU, China and India. In addition, the Chair should be someone comfortable with facilitating a process, both in terms of keeping time and order, and potentially mediating conflict. Instructors were also instructed to consider assigning students roles that run counter to their own experiences or perspectives; for example, an environmentalist could be assigned the role of the World Coal Power Association, an industry lobbyist. This approach can help students think about how different parties conceive of the problem and solution.

**Table 2. Roles in the Mercury Game**

<b><i>Countries</i></b>
Brazil, representing the Group of Latin American and Caribbean Countries (GRULAC)
Canada
China
European Union
India
Japan, acting as the Chair of the negotiations
Tanzania, representing the African Group
United States
<b><i>Non-governmental organizations (NGOs)</i></b>
Mercury Free Future (MFF), an advocacy group



The Arctic Council's Arctic Monitoring and Assessment Programme (AMAP), a governmental science body
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World Coal Power Association, an industry group
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Through this scientific assessment and the role descriptions, the game provides realistic background on mercury as a global pollutant. Over the past several decades, scientific studies have shown that mercury is a persistent pollutant in the environment, and that it cycles globally (Selin 2009). Mercury remains in ecosystems for decades to centuries once mobilized. Further, mercury poses health risks, particularly when in the form of methyl mercury, because it is a neurotoxin. Health effects are especially acute in utero, when exposure can cause long-term cognitive and developmental defects (National Academy of Sciences 2000). Eating predatory fish containing methyl mercury is by far the most significant human exposure pathway (Arctic Monitoring Assessment Programme 2011). Since some northern indigenous communities consume large quantities of marine mammals, they can be highly exposed. Mercury also poses environmental risks, particularly to the Arctic where it accumulates in food webs. In addition, mercury is used in artisanal and small-scale gold mining because it binds to gold well, creating an amalgam. When it is burned off, workers can be exposed to mercury at very high levels.

Using scientific information on these issues, the game focuses on source credibility, strategies for representing risk and uncertainty, and the balance between scientific, political and economic considerations during international environmental negotiations. For example, the game portrays scientists in a number of different roles. Some of the country representatives are themselves scientists, who view the common scientific assessment from a different perspective depending on their national circumstances. One player takes on the role of an industry scientist, who casts doubt on the assessment, while another role represents an NGO advocacy group actively lobbying for prompt and sweeping global action. A third player represents an intergovernmental scientific body, which presents information to the group without taking a position on any of the issues. These roles show students that science and scientific actors come with varying points of view. Other players then need to consider the contrasting perspectives each scientist presents, while evaluating their credibility. As a result, players must grapple with how and why science can become politicized.

In addition to grappling with the role of science, like other international environmental role-plays such as the Chlorine Game (Najam 2001), the Mercury Game explores the dynamic between the developed and developing countries. For many students, concepts including “common but differentiated responsibilities” and “the precautionary principle” are new, yet these challenges are at the heart of most

treaty-making efforts. In a game setting, these ideas are animated through players' positions, rather than being static, abstract concepts. Although the game is specific to an international chemical regime, which has particular political and technical issues (Selin and Selin 2006; Selin 2010), this North-South dynamics allow generalizations beyond chemicals policy to environmental negotiations broadly.

To evaluate how playing the game changed students' knowledge and perspectives, we used pre and post game surveys. The surveys assessed knowledge and learning through self-reported measures as well as skill-testing questions. It also attempted to measure content and process based knowledge, such as whether players' beliefs about scientific uncertainty changed as a result of playing the game. Open-ended questions allowed students to report major insights. For the quantitative questions, we analyzed participants' answers using paired t-tests for each individual's responses to the pre and post surveys. Since each student is only compared against his or her earlier answer, potential differences in students' interpretations of the scales do not impact the results. For the qualitative, open-ended questions, we categorized and grouped the students' answers, particularly focusing on differences between science and social science students. We present both the quantitative and qualitative results from the surveys in the next section.

### **Results: Evaluating how negotiation simulations affect learning**

Between 2011 and 2013, the mercury game was played in 9 university classrooms where students completed and submitted surveys before and after playing. In some cases, students filled out paper copies while in other cases they used an online survey; but, in both cases, the questions were the same. Overall, we received survey results from 151 science students and 34 social science students. Scientists, negotiators and other people also played the game outside universities, but we do not report their survey results here. We analyzed and report results for science and social science students separately, as there are noteworthy differences in knowledge and learning between these two groups.

#### *Learning*

We assessed students' learning about mercury science and policy through several self-reported measures. Both science and social science students reported an increase in their knowledge of mercury science after playing the game. Not surprisingly, science students reported a higher level of mercury science knowledge both before and after the game compared to social science students. Social science students reported lower confidence in their scientific knowledge, but still reported higher scientific knowledge after playing the game compared to before the game.

For policy knowledge, science students reported low levels of mercury policy knowledge before playing the game, but became more confident in their policy knowledge after playing the game. Social science students reported beginning the

game with higher levels of policy knowledge compared to science students, but they also improved their policy knowledge by playing the game. While social science students report higher knowledge of mercury policy than science students after the game, the science students have largely closed the policy knowledge gap (see Table 3).

**Table 3. Self-reported Knowledge of Mercury Science and Policy Before and After playing the Mercury Game**

Measure	Pre-game mean	Post-game mean	Difference in means
How would you rate your knowledge of <b>mercury science</b> ? <i>Science students</i> <i>Social science students</i>	2.49 (0.71) 2.35 (0.81)	3.60 (0.67) 3.49 (0.70)	1.09*** 1.13***
How much do you think you learned about <b>mercury science</b> from playing the game? <i>Science students</i> <i>Social science students</i>		3.82 (0.90) 3.66 (1.11)	
How would you rate your knowledge of the international <b>mercury negotiations and options for mercury policy</b> ? <i>Science students</i> <i>Social science students</i>	1.87 (0.68) 2.35 (0.92)	3.65 (0.70) 3.79 (0.73)	1.77*** 1.44***
How much do you think you learned about the international <b>mercury negotiations and options for mercury policy</b> from playing the game? <i>Science students</i> <i>Social science students</i>		3.88 (0.82) 3.96 (0.89)	

Results are from 1 (very poor/little) to 5 (very good/much). Standard errors are shown in brackets. \*\*\* indicates p-value significant at 0.001 level in a paired t-test.

We also asked students to report what they learned about mercury science from playing the game through open-ended questions. Students were asked, “What did you learn about mercury science from playing the game?” Many science students gave sophisticated answers to this question, discussing global transport, the toxicity of different forms of mercury and the major sources of atmospheric emissions. After reading the assessment and playing the game, science students were able to clearly identify chemical forms of mercury and their differential ability to transport globally and bioaccumulate. Some science students also discussed uncertainty, and how science can be framed in varying ways to fit different positions and narratives. Most science students concluded there was sufficient evidence of harmful effects from mercury to motivate action on a global treaty.

In contrast, the majority of social science and policy students did not report learning detailed scientific information about mercury. Most did not clearly identify key specific facts, such as mercury's ability to transport globally or the differential toxicity of its various forms. Instead, social science students reported learning more general facts, including that mercury cycles in the environment, harms humans and ecosystems, and comes from various processes. In contrast to the science students, social science and policy students were more focused on the politicized nature of science in the negotiation process. For example, one student stated that s/he learned, "That peer reviewed science will not always work; that anthropogenic sources are a major but not exclusive problem." While some science students made similar remarks, these points were more common amongst social science students.

To evaluate policy learning, we asked open-ended questions about how developed and developing countries view the mercury problem. We were looking for whether students could distinguish between developing countries' concern for funding and capacity building, and many developed countries' interest in exporting their higher environmental standards globally. Science students were able to identify that developed countries were concerned about health and global transport, and willing to offer assistance if developing countries took on commitments. They had more difficulty understanding developing countries' positions and interests.

In contrast, social science students correctly identified financial and technical assistance as a key issue for developing countries before agreeing to a legally-binding treaty. They also understood that developed countries had already reduced their emissions, and needed developing countries to act. In contrast to the results on science learning, social science students were more likely to be specific about the economic and political dimensions, while science students were more likely to interpret these questions as scientific rather than policy questions.

### *Knowledge*

Apart from self-reported learning measures, the pre and post surveys also included factual questions about mercury science and policy (see Table 4 for questions). Both groups of students improved on objective, skill-testing questions concerning mercury science. One science question asked students to identify the major sources of mercury emissions by sector, ranking them from largest to smallest. The correct answer was coal combustion, ASGM, metal production, waste incineration and the chlor-alkali industry. Both science and social science students were able to rank the major sources of mercury by sector with greater accuracy after playing the game. Another group of science questions asked students to estimate the importance of various exposure pathways for mercury. After playing the game, science students doubled the amount of correct answers they gave to these exposure pathway questions. Social science students also improved in these questions, although the average number of correct answers increased by only 50%.

Skill-testing policy questions asked students to identify whether mercury policy would lead to various outcomes, from health impacts to energy cost changes. The policy questions asked students to identify whether new mercury policy would improve people's health, improve ecosystem health, cause energy prices to rise, or require financial resources. In practice, mercury regulation would lead to all four outcomes. We hypothesized that science students would know *a priori* about human and ecosystem health, while social science and policy students would consider costs. We found that science students learned about mercury policy's effects on ecosystems, and about the costs of new policy, although neither were statistically significant changes. Social science students learned that energy costs can be impacted by mercury policy and that mercury policy can be expensive. Before playing, social science and policy students thought less about energy costs than the science students, and more about human health impacts. This is surprising, given that the science student sample included public health students. An unexpected result was that social scientists seem to have decreased their belief that mercury policy will affect ecosystem health after playing the game; it is possible that this occurred because of the small sample of social science students. On the other three questions in this section, social science students were more correct on the post-surveys.

**Table 4. Skill Testing Knowledge Questions**

<b>Questions</b>	<b>Correct answers</b>
<p>Without consulting a reference, what do you think are the largest sources of anthropogenic mercury emissions? (Rank order)</p>	<p>Coal combustion* ASGM Metal production Waste incineration Chlor-alkali production</p>
<p>How do you think people become exposed to mercury?</p>	<p>People who eat more fish will have higher mercury content in their hair compared to those people who eat less fish – <i>almost always true</i>.</p> <p>The majority of the mercury in most people's bodies originated from human emissions – <i>almost always true</i>.</p> <p>Mercury contamination in most waterways is a result of local discharges, such as dumping or industrial wastewater – <i>usually not true</i>.</p> <p>The most dangerous form of mercury for human health is elemental mercury, found in some lightbulbs – <i>almost never true</i>.</p>
<p>Check all [statements] that you believe are true. If my nation takes steps to reduce mercury emissions it will...</p>	<p>Improve people's health – <i>true</i> Improve ecosystem health – <i>true</i> Cause energy prices to rise – <i>true</i> Cost significant amounts of money – <i>true</i></p>

\*Note: UNEP's 2013 mercury assessment ranked ASGM higher than coal combustion, revising earlier estimates, although the game materials clearly rank coal combustion higher per best estimates at the time.

### *The role of scientific uncertainty*

Before playing the game, science students rated scientific uncertainty as an important barrier to negotiating international environmental treaties. After playing the game, they continued to hold this view. Social science and policy students, however, ranked scientific uncertainty as a more important barrier *after* playing the game. This change was also statistically significant at the standard level 5%, despite the small sample. This suggests that social science students interested in environmental policy may not recognize the key role for science and scientific uncertainty. Through playing the mercury game, they come to appreciate this dynamic to a greater extent.

Social science students' lower attention to scientific uncertainty is also echoed in the open-ended survey questions. Students were asked, "Having played the game, what do you think are some of the challenges of integrating scientific information into an international environmental negotiation?" Science students focused on simplicity and clarity as key issues to presenting scientific information in a negotiation. They also talked about uncertainty and the source of the information as barriers to different parties accepting the science. One science student put it this way: "Having scientific data creates interest in the issues that draws public attention and therefore policymakers' attention. Getting scientific information is only the first step in policymaking: the difficult part is to have everyone's needs be met and for everyone to agree on a plan that reaches everyone's needs." This student is distinguishing between science's role in agenda setting versus politics' role in bargaining over how to structure a global treaty, an impressive inference.

While social science students also discussed scientific uncertainty, their comments focused on specific actors, discussing how interest groups could either support or hinder the negotiation. One student argued that NGOs should be integrated throughout the entire negotiation process. Social science students also pointed to procedural and structural barriers, such as the difficulty for negotiators to update their position at the table, and the fact that there was no formal way for science to be integrated into the process. Here again, we see science students and social science students' bringing their divergent training and experiences to their analysis of the negotiation game. As a result, science students and social science students differ in their learning and reflections on scientific uncertainty after playing the game.

### **Discussion**

Our results show that The Mercury Game contributes to learning for both science and social science students interested in environmental policy and negotiation. For science students, the game deepens their knowledge of mercury science and policy. In addition, it presents them with potential roles they could play in future careers as

policy-oriented scientists. This process can help them think about what kind of role they may want to take on at the science policy interface (Pielke Jr. 2007).

Although the game has been played with fewer environmental studies students from the social sciences and public policy to date, the evidence suggest it also helps build their content and process knowledge. Although they gain less knowledge of specific scientific details, the game gives these students the opportunity to see how science is used in policymaking and think about the role uncertainty plays. Social science students were also able to pick up some of the subtleties of the policy and negotiation dynamics that the science students missed.

The findings on learning presented in the results section suggest that science students learn specific scientific information through a negotiation simulation at the science policy interface, while social science students grasp broad scientific concepts while missing many of the specifics. Conversely, while science students are able to see that economics and politics matter for environmental policymaking, they struggle to devise new ways of proceeding that might increase the importance of science. Social science students leave the game with new ideas for how changing the negotiation process might lead to better outcomes. For example, one student stated, "the scientific background was useful and important, but because there was no formal way for science to have a "stake" it got lost in the negotiations". Together, this suggests that the social science students tend to focus on the policy process when they play the game and expand their knowledge in this area.

Clearly, the game cannot teach social science students enough science to bring them on a level ground with science students in three hours, nor can it teach science students enough policy. Instead, the game deepens each group's respective knowledge base, while exposing the students to concepts, challenges and perspectives they may not have considered.

Apart from our use of surveys, our limited ability directly observe the game in its application in nine separate universities, in different courses, is a source of uncertainty in our results. Each course had a different syllabus and professor, which may affect the context of our results. In addition, while we asked professors to instruct participants to fill out the pre-survey *before* reading the game materials; we have no way of determining whether they may have completed the pre-survey *after* reading their role and the assessment. If students read the materials before the pre-survey, we would expect to measure less learning in our experiment overall, since students would have higher baseline knowledge on mercury before they completed the survey simply through completing the readings. Further, we also do not expect this potential for pre-reading to differ between science and social science students. Thus, we expect that this effect could mean we are under-estimating potential learning from the simulation.

In addition, our sample size for social science students was small. Since all the surveys were collected from classrooms in North America, it is possible these



results could vary if the game was played elsewhere. However, considering these experimental limitations, the survey evidence nevertheless shows that the mercury game is an effective way to teach students about science-policy during one class session.

## **Conclusion**

Teaching students about the complex role science and policy play in environmental negotiations and decision-making is challenging. For science students, political and economic considerations may not be primary in their minds. For environmental studies students from the social sciences and public policy, scientific concepts may be unfamiliar. Playing a simulation such as the mercury game may help to fill each of these gaps while deepening students' existing expertise in their own disciplines. Further, the game allows educators to talk about the boundary between science and policy while grounding this abstract discussion in students' experience.

Although the game is fictionalized, the uncertainties represented in the game reflect the challenges in the actual mercury treaty negotiations, which concluded in 2013. For example, the mercury assessments issued in the mid-2000s were quite uncertain about the proportion of anthropogenic emissions that came from artisanal and small-scale gold-mining (ASGM). While the 2008 UNEP scientific assessment suggested it was the second largest source, the point estimate had large error bars, placing total emissions somewhere between 250 to 500 tonnes annually. By the 2013 scientific assessment, ASGM was the largest source, with the revised estimate at over 700 tonnes annually – an estimate outside of the error bars in the 2008 report. As the 2013 report concluded, this increase was likely due to estimation problems rather than a growth in emissions. Critically, this revised information had the potential to change the interpretation of nature of the problem. Rather than being, first and foremost, an issue of centralized emissions from coal plants and other industrial activities, a large amount of mercury was coming from dispersed, poor, small-scale gold-miners. Addressing this source would require a different approach than conventional pollution control technology.

While the mercury game teaches environmental science and studies students about one, specific environmental negotiation, we believe it accurately models how science is used more broadly in environmental treaty negotiations, including the current UN climate change talks. Common negotiation themes, such as the extent of financial and technical assistance necessary, and the importance of historic versus current emissions, cut across all international environmental negotiations. Similarly, environmental problems are often a blend of local and global impacts. And in every case, science is uncertain. Devoting one class period a semester to these topics is no doubt important to both environmental science and studies students' education. In our experience, using a negotiation simulation makes these abstract tensions at the science-policy interface concrete, memorable and engaging.

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