Intrinsic Ethics Regarding Integrated Assessment Models for Climate Management

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Abstract:
In this essay we develop and argue for the adoption of a more comprehensive model of research ethics than is included within current conceptions of responsible conduct of research (RCR). We argue that our model, which we label the Ethical Dimensions of Scientific Research (EDSR), is a more comprehensive approach to encouraging ethically responsible scientific research compared to the currently typically adopted approach in RCR training. This essay focuses on developing a pedagogical approach that enables scientists to better understand and appreciate one important component of this model, what we call *intrinsic ethics.* Intrinsic ethical issues arise when values and ethical assumptions are embedded within scientific findings and analytical methods. Through a close examination of a case study and its application in teaching, namely, evaluation of climate change integrated assessment models, this paper develops a method and case for including intrinsic ethics within research ethics training to provide scientists with a comprehensive understanding and appreciation of the critical role of values and ethical choices in the production of research outcomes.

1. Introduction

Recent publications in the area of responsible conduct of research (RCR) education call for a more comprehensive approach to understanding and teaching RCR (Brown and Kalichman 1998; Kalichman 2007; Kalichman 2002; Kligyte 2008a; Kligyte 2008b; Pimple 2002; Plemmons 2006; Steneck 2006). While these various conceptual and practical approaches to teaching RCR do not converge on an optimal approach, there is general agreement that two key objectives of RCR education are to produce a positive change in attitudes regarding research ethics and increase knowledge of RCR principles and awareness of the relevance of ethical issues in research with the aim of reducing instances of misconduct. Kalichman (2007) suggests that successful RCR education would inform and support actions designed to minimize research misconduct, such as promoting the development of ethical decision-making skills and educating researchers regarding their responsibility to report instances of misconduct, as well as promoting positive attitudes towards RCR. Steneck (2006) similarly argues for a broader conception of RCR that would result in research that is conducted so that it meets the responsibilities and expectations set forth by professional organizations, research institutions, and the public.

[†]Erich W. Schienke and Nancy Tuana were responsible for framing and drafting the manuscript, with input as noted from the other co-authors. They also developed the theoretical framework of the Ethical Dimensions of Scientific Research program. Seth Baum drafted sections on the module development and the ethical aspects of cost discounting and contributed to the discussion on intrinsic ethics. Kenneth Davis developed the educational module and contributed to the discussion on ethics pedagogy. Klaus Keller contributed to the discussion on climate integrated assessment models. All authors contributed to the writing of the manuscript.

Despite such efforts, we contend that there still remains a significant gap in research ethics pedagogy. In this essay we propose a new approach to research ethics training that illustrates that ethical inquiry is an integral dimension of the design and production of scientific research.

One key requirement for adequate training in research ethics is to account for the full range of the ethical dimensions of scientific research. While current RCR pedagogical strategies are an important component of research ethics, these strategies typically miss two significant dimensions of research ethics. This essay focuses on clarifying and illustrating one domain of research ethics overlooked in traditional approaches to RCR, what we label *intrinsic ethics*. We argue that training in this area of ethics is essential to a full appreciation of the role of ethics within scientific research.

The paper opens with a description and overview of the model of research ethics that we advocate and label the Ethical Dimensions of Scientific Research (EDSR). In Section 3, we discuss a case study, namely, integrated assessment models for climate change management, designed to illustrate how values and ethical issues are embedded in scientific research. Section 4 is designed to provide a more general overview of intrinsic ethics and outline a pedagogical approach to teaching students in the sciences to recognize that values and ethical issues are often embedded in scientific research. In this section we offer a general framework for identifying ethical issues that originate from within the practice of science, that is, are instances of what we label intrinsic ethics. The primary conclusion is that *intrinsic ethics* is a missing and necessary dimension of ethics training in the sciences.

2. The Ethical Dimensions of Scientific Research

The results of a three-year NSF-funded collaboration between scientists and ethicists revealed three distinct approaches to teaching ethics to graduate students in the sciences. The first approach is the ethics of research procedure and dissemination, which we label procedural ethics. This approach is the focus of typical RCR training (Steneck 2007; Steneck 1999; Pimple 2002; Rhoades 2002). The second approach, which we label extrinsic ethics, became apparent through our efforts to incorporate training in NSF's second merit review criterion (the "Broader Impacts" Criterion). The broader impacts criterion addresses the impacts of the research in terms of enhancing scientific research and education, including underrepresented groups, and how the research benefits society. (Schienke et al. 2009; NSF 1996; Schrader-Frachette 1994). The third approach, intrinsic ethics, became apparent as we identified a series of ethical issues and values embedded in scientific analyses.

We have developed and assessed a more robust model of research ethics training (Schienke et al. 2009). This model, which we have titled the Ethical Dimensions of Scientific Research (EDSR) (see Figure 1), includes all three components of research ethics training, namely:

1) **Procedural ethics**: ethical aspects of the process of conducting scientific research and disseminating results, such as: falsification, fabrication, and plagiarism; care for subjects (human and non-human animal); responsible authorship issues; analysis and care for data; and conflicts of interests. Procedural ethics is contained almost entirely within the currently defined goals of RCR.

2) **Extrinsic ethics**: ethical issues extrinsic to the production of scientific research, i.e. ethical issues that involve issues that are external to scientific practice.[1] These arise, for example, when considering the impact of scientific research on society. The above include: the impact of funding on research trajectories, the effects of technological innovations on social ends such as health and well-being, and the role of science in policy making.

3) **Intrinsic ethics**: ethical issues and values that are embedded in or otherwise internal to the production of scientific research and analysis. These involve, ethical issues arising from, for example: the choice of certain equations, constants, and variables; analysis of data; handling of error, and degree of confidence in projections.

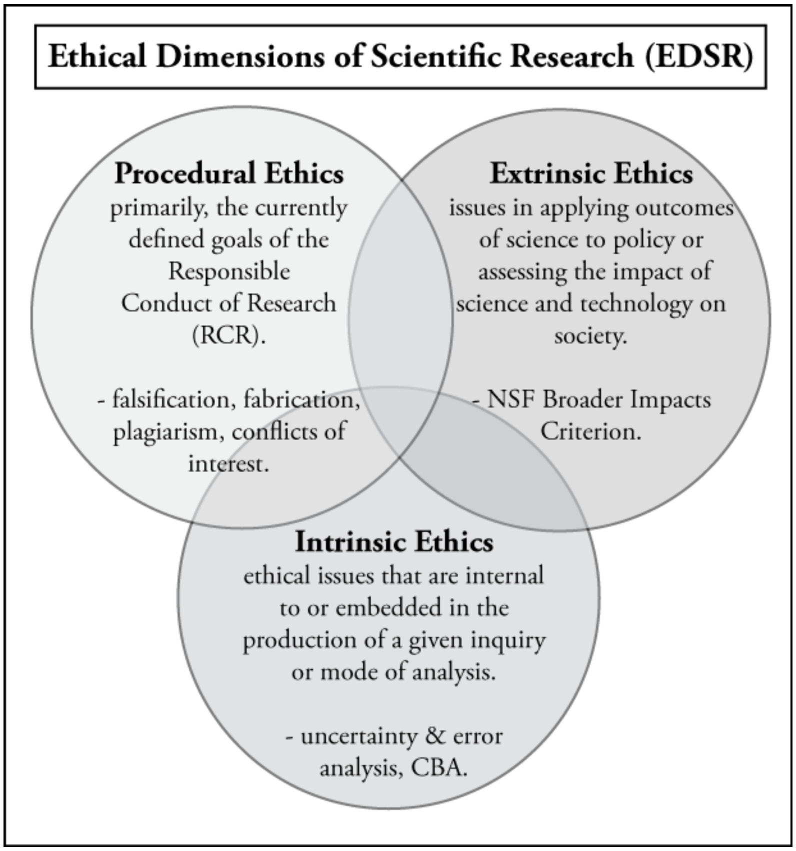

Figure 1. Domain diagram of the Ethical Dimensions of Scientific Research[2].

As is argued previously in Schienke et al. (2009), RCR education that focuses solely or primarily on the first dimension by only teaching proper research behavior and procedure is not sufficiently comprehensive for those sciences that employ the U.S. National Science Foundation

[1] Our distinction between intrinsic and extrinsic parallels to some extent Brian Ellis' (2001) drawing of the distinction between intrinsic/extrinsic property in science. Our conception, while applied to ethics, does not mirror the intrinsic/extrinsic value distinction.

[2] The purpose of representing the EDSR program as a Venn Diagram is to reinforce the understanding that ethical issues can present in multiple dimensions in the process of conducting scientific research. Further, an ethically robust analysis of scientific research is one that would take into consideration all three ethical dimensions. Sometimes issues may overlap, and intrinsic choices can certainly have extrinsic impacts. This is an example where the two dimensions would overlap, as represented in the diagram.

(NSF) merit criteria for proposal reviews, in particular, the broader impacts criterion. The NSF requires researchers to identify not only scientific and intellectual merit (first criterion) of a given research proposal, but also to address considerations of broader impacts (second criterion) of research on the infrastructure of science and on society. As such, we argued that typical RCR training, what we refer to as *procedural ethics,* does not provide the training needed to respond to the requirements of the NSF second criterion, the broader impacts criterion. Although projects funded by the National Institutes of Health (NIH) do not explicitly require consideration of broader impacts, we argued that the broader impacts criterion raises a set of ethical considerations that are potentially relevant to *all scientific research* and thus should be a component of all training in research ethics (Schienke et al. 2009).

In this essay we focus on the third component of a fully adequate approach to research ethics, namely, *intrinsic ethics.* To more fully represent the nature and importance of this approach, the following section will clarify and justify the importance of this approach to research ethics by discussing a pedagogical module on intrinsic ethics.

3. Intrinsic Ethics Case Study: A comparison of integrated assessment models of climate change strategies

In this section we work through a case study comparing two studies using integrated assessment models (IAMs) to analyze climate change management strategies (Nordhaus 1992; McInerney and Keller 2008). Both of these studies address the overarching problem of identifying an economically optimal trajectory of investments in reducing greenhouse gas emissions. Choosing the criterion to define "optimality" (technically, the objective function of the underlying optimization) is, of course, a value judgment. The two studies illustrate the nature and importance of intrinsic ethics as well as demonstrate the capacity for environmental science graduate students to identify and discuss intrinsic ethics. We offer this as an example of intrinsic ethics and provide an in-depth analysis of the case study to clarify how ethical issues arise internal to scientific research, and apply a typology (see Section 4) to the case to demonstrate how others may be able to reconstruct an intrinsic approach.

The case is based on an instructional module we developed and implemented for a graduate course on the global carbon cycle.[3] The module is designed to help graduate students in environmental sciences identify and analyze ethical issues that arise in the context of scientific research that are of the sort that they are likely to encounter in their scientific careers. Though the module was designed for a global carbon cycle course, it would be of interest to graduate courses covering other aspects of climate change and related topics.

The module is presented during one class period and matches the format of other class sessions in the course. Students were previously assigned two readings on the topic of climate management: a "classic" paper in the field, Nordhaus (1992), and a more recent paper, McInerny

[3] The global carbon cycle in this context describes the processes governing the budget of carbon in the Earth's atmosphere, including exchanges among the major carbon pools active on time scales relevant to contemporary climate change. These carbon pools are the atmosphere, the terrestrial biosphere, the oceans, and fossil fuel reservoirs (Schlesinger 1997). Since carbon dioxide and methane, both carbon-containing gases, are the principal drivers of anthropogenic climate change, understanding the carbon cycle and potential methods of managing the carbon cycle are important topics in the study of climate change (IPCC 2007).

and Keller (2008). The results of these papers were introduced in a prior lecture that demonstrated how climate management research evolved from a relatively simple, "pioneering" study towards more detailed analyses, paralleling research on the physical and biological aspects of carbon cycle science presented elsewhere in the course.

The module consists of instructor-facilitated discussion guided by a series of slides.[4] The instructor presents several discussion questions (described below) for the students to consider as the module is introduced. These questions ask the students to consider whether or not there are ethical issues embedded in the Nordhaus (1992) or the McInerny and Keller (2008) analyses and, if so, to consider the corresponding implications for researchers who work on similar analyses. Then the instructor conducts a review of the economic equations central to the IAMs of the two approaches (Equations 1-3 below). At this point the instructor asks the students to examine these equations and to identify both their factual and their ethical content. The instructor then returns to the original discussion questions and uses them to encourage an open-ended discussion about values and ethical issues that arise in the context of climate management research. Finally, students are presented with outlets for further reading regarding ethical issues in climate management, including academic literature (Tol 2001; Stern 2007; Baum 2007) and online resources.[5] Throughout the module, emphasis is placed on how different ethical assumptions as well as different degrees of complexity in the description of the physical climate system can yield different recommendations regarding carbon (thus climate) management.

The module's discussion questions promoted an open and focused discussion of the ethical issues embedded in the IAMs. The instructor encouraged the students to not only identify ethical issues that fall into the category we've labeled "intrinsic ethics," but also to formulate alternative approaches to climate management reflecting alternative ethical assumptions. The aim was not to not judge any specific ethical views the students advanced, but instead to offer space for discussion of whatever views the students might put forward. When discussion would occasionally drift towards the physical sciences underlying the IAMs and away from the ethics, the instructor would interject to keep the discussion focused on ethical issues. This approach, which relied upon the students to identify and articulate ethical issues on their own and without prior formal instruction in ethics, engendered an atmospheric of discovery and ownership of these concepts among the students, and facilitated an engaged and constructive discussion of intrinsic ethics. During the course of the module presentation and discussion, students were not introduced to the EDSR program and explicit distinctions were not made between intrinsic, extrinsic and procedural ethics. However, the module provided them with an example of intrinsic ethics and discussion mainly focused on intrinsic issues. We recommend this approach to other instructors.

To expand on this pedagogical outline, Section 3.1 provides background information about IAM. This discussion is less detailed than would be presented in class, but provides the reader with some of the content students would be exposed to. Section 3.2 provides the list of the discussion questions used to facilitate ethical reflection, and focuses on ethical issues identified by students

[4] These freely available materials are located online at: http://rockethics.psu.edu/education/environment

[5] The online resources presented are: American Statistical Association Ethical Guidelines for Statistical Practice, http://www.tcnj.edu/~asaethic/asagui.html; The Online Ethics Center for Engineering and Science, http://onlineethics.org/index.html; Ethics of Climate Change, http://ClimateEthics.org

in the module session. In the application of the intrinsic typology in Section 4, we also provide a brief discussion of additional ethical issues that students or the instructor might identify in addition to those that arose in the actual class session.

3.1. An Overview of Integrated Assessment Models of Climate Change (IAM)

IAMs are often used to analyze possible societal responses to climate change, in particular, reductions of greenhouse gas (primarily carbon dioxide) emissions. The research achieves this by building models of the global climate-society system. These models are known as *integrated assessment models* because they integrate content from a wide range of disciplines (Risbey and Kandlikar 1996; Parson and Fisher-Vanden 1999). There are many types of IAMs, integrating content from a broad range of disciplines. The models discussed in this module integrate information primarily from climate science (i.e. the discipline studying the physical climate system) and from economics.

IAMs are sometimes used to determine climate management strategies that optimize "utility," a measure of time-aggregated societal wealth. Both papers presented in the module (Nordhaus 1992; McInerny and Keller 2008) share the same optimization structure. However, McInerny and Keller (2008) also add an inviolable constraint to this optimization structure that it is impermissible to exceed a certain probability of triggering a collapse in the North Atlantic meridional overturning circulation (MOC).[6] McInerny and Keller (2008) adopt this constraint because optimal climate management strategies are sensitive to the chosen management criteria. In McInerny and Keller (2008), the MOC constraint must be satisfied in a probabilistic sense, regardless of the implications for the total net benefits. The difference between the two approaches, namely, whether to represent the MOC threshold or not is both a function of description within the governing equation *as well as a difference in values* (as will be explained in Section 4, below).[7]

The optimization structure used in the two papers is known as the Ramsey-Koopmans-Cass "optimal growth" model (henceforth the RKC model) (Ramsey 1928; Koopmans 1965; Cass 1965). This model maximizes a discounted sum (W) of globally aggregated utility (U), defined as:

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[6] The MOC is part of a global-scale ocean circulation system also referred to as the "conveyor belt circulation" (Broecker 1991). In the North Atlantic, this circulation system consists of warm surface waters flowing from the tropics to higher latitudes. Due to heat loss to the atmosphere and brine rejection due to sea ice formation, some water parcels become denser than the underlying water masses and form deep waters. These deep waters then return southwards to the tropics (and flow further south). The overall flow problem in the North Atlantic is hence a meridional overturning, hence the name MOC. The MOC may collapse in response to anthropogenic CO_2 emissions (Meehl et al. 2007). An MOC collapse is predicted to pose special risks to natural and human systems (Schneider et al. 2007).

[7] Unconstrained optimization and threshold constraints are two commonly used means for determining optimal climate management paths. While perhaps not the intention of the papers, the decision to include a probabilistic optimization constraints such as the MOC constraint in McInery and Keller (2008), where Nordhaus (1992) does not, was recognized by the students as a difference in embedding values and not just as a difference in the descriptive capacity between the assessments.

$$W = \sum_t U[c(t), L(t)](1+\rho)^{-t} , \qquad (1)$$

where U is defined by

$$U[c(t), L(t)] = L(t)[c(t)^{1-\alpha} - 1] / (1-\alpha) , \qquad (2)$$

In these equations, t is time, c is per capita consumption, ρ is the utility discount rate, which is used to compare the value of future utility with the value of present utility, L is the population, and α is a elasticity parameter characterizing the relationship between utility and consumption. Per capita consumption is a function, for example, of the globally aggregated economic output, the investment in capital, damages of climate change, and investment in reducing greenhouse gas emissions. The optimal climate management strategy is determined by optimizing the objective function (W in equation 1).

Equation 1 defines how the effects of a given strategy are aggregated and compared over time. Present and future utilities are compared via the utility discount rate (ρ). If $\rho=0$, then a unit of utility holds the same value regardless of when it occurs. If $\rho>0$, then a unit of utility holds less value if it occurs in the future than if it occurs in the present. If $\rho<0$, then a unit of utility holds more value if it occurs in the future than if it occurs in the present. Much debate in the climate change management literature centers on determining the proper value for ρ (c.f. Nordhaus 2007; Stern 2007).

The relationship in Equation 2 is such that there can be diminishing marginal utility of consumption. In other words, as one's consumption increases, the utility one gets from an extra unit of consumption decreases. Equation 2 is thus an implementation of the idea that a dollar is worth more (holds more utility) to a poor person than to a rich person – or, in this case, a dollar is worth more in a time period with lower average income than in a time period with higher average income. The elasticity parameter (α) is a measure of how much more a unit of consumption is worth to the poor than to the rich. Higher values for α mean that a unit of consumption is worth more to the poor; lower values for α mean that the difference is relatively small. Equation 2 also represents the idea that the total amount of utility is the product of population (L) and the per capita utility.

The choices of ρ and α have a major effect on what the models find to be optimal climate change policy (i.e. optimal emissions reduction or optimal carbon tax). This is for two reasons. First, reducing emissions in the model involves near-term losses in exchange for future gains. How utilities are aggregated over time is defined by ρ. As ρ increases, future utilities become less important, which in turn makes the future impacts of climate change less important and thus typically leads to a lower optimal level of emissions reductions. Second, future time periods are typically increasingly wealthy in the economic optimal growth models (i.e. consumption increases over time). How the value of consumption is compared between the wealthy and the poor is defined by α. As α increases, the consumption of future, wealthier time periods holds less value, which also makes the impacts of climate change less important and leads to a lower optimal level of emissions reductions and a lower carbon tax. Thus, higher values of ρ and α lead to lower optimal levels of emissions reductions; lower values of ρ and α lead to higher optimal levels of emissions reductions. Nordhaus (2007) finds that changing the values of ρ and α can lead to optimal carbon taxes that differ by a factor of ten. Given that the RKC model is being used to evaluate climate change policy, how ρ and α are specified are crucial issues.

As noted above, the analysis of McInerny and Keller (2008) applies a probabilistic MOC constraint to the optimization criterion. This constraint requires that any climate policy keep the probability of an MOC collapse below a certain probability threshold. The constraint is significant in that it serves to eliminate certain policies that do not meet the probability threshold. Among the remaining policies, the policy that maximizes the optimization criterion is the policy that is recommended. Thus, the recommendations in McInerny and Keller (2008) are also sensitive to the choices of ρ and α.

3.2. Integrated Assessment Models of Climate Change and Intrinsic Ethics

The IAMs sketched above raises many important instances of intrinsic ethics. Students identified many of these ethical issues during the module session. An important result from our experience is that graduate students in environmental science (and presumably other subjects as well) are quite capable of identifying and discussing intrinsic ethics.

After reviewing the governing equations, the students were asked to address the following questions: 1) What value judgments are embedded in economic optimal growth models for climate management strategies? 2) Can we articulate the value judgments that are implicit in a given analysis framework? 3) Is there a valid case for "ethical uncertainty" in climate management optimal growth analyses? 4) What, if any, are the implications for your research? 5) What are the implications for ethical use of the results of such economic optimal growth analyses? Most of the discussion time was spent on the first question, with some discussion of the second and third questions. The last two questions were not addressed in class due to limited time.

In response to the first discussion question, students rapidly identified a large number of intrinsic ethical issues. Much of the students' discussion focused on the definition of global utility, i.e. the variable W. The students noted the embedded assumption that optimizing global utility, summed over time, does not distinguish between a population that consists of both the wealthy and the poor, and a population where well-being is equally distributed. In other words, the global utility does not distinguish between situations where consumption is distributed evenly from situations where people in some regions consume a lot (are very wealthy) while others consume little (are very poor), as long as the globally aggregated utility in these situations is the same. The lack of spatial disaggregation comes from the fact that the consumption variable (c) is the total consumption of the global population during a given time period.

Students also noted that aggregated global utility is proportional to population. That is, a larger population results in a larger amount of consumption, c. The students viewed this as a value-based choice as well.

The students found the imposition of the additional constraint beyond maximizing utility that appears in McInerny and Keller (2008) to reflect ethical judgments. The analysis of McInerny and Keller (2008) compares the results on an optimization with and without the constraint that the probability of MOC collapse cannot exceed a specified limit. Among climate management strategies that satisfy the probabilistic "MOC preservation" constraint, the strategy that maximizes utility is chosen. Students noted that inclusion of a constraint is a value-based choice. The students felt that it was not possible to say whether or not avoiding MOC collapse is correct or incorrect; it depends upon the values of those managing the climate. Students also noted that the choice of constraint, and the level of tolerance for violating the constraint (in this case, the probability of MOC collapse), also represented ethical judgments.

The students identified the choices of the utility discount rate, ρ, and the elasticity parameter, α, as value-laden and thus another instance of intrinsic ethics relevant to the IAM, and noted the implications of different choices of these two parameters, as discussed above.

The students also noted that the quantification of climate-related damages in climate IAM likely contained value judgments. The damage definitions in the RKC model for climate change convert various climate change impacts – droughts, floods, etc. – into units of money and utility. Ethical issues are embedded in this conversion. The nature of the conversion is described in more detail in references cited in these papers, however, and class time did not allow for more detailed investigation of this matter.

In response to the second question, students did not spend time naming the value judgments intrinsic to the IAM equations, rather they proposed alternative formulations to these equations that were equally defensible but represented alternative sets of values. The two papers studied by the students illustrated one alternative. McInerny and Keller (2008) added the option of the MOC collapse threshold, which represents a value for preservation of the natural system for its own sake. The students recognized this as an alternative value system, not a facet of the physical or biological sciences that could be proven right or wrong. We note also that this threshold can make a dramatic difference in the optimal management strategy, a point that was clearly appreciated by the students.

Students were not asked to judge whether this choice was right or wrong. The point of the exercise was to help them see that how a researcher formulates the IAM can be a value-based choice with ethical implications.

The students clearly felt that the choice of optimizing globally aggregated utility was a strong ethical assumption that was open to alternative formulations, leading to significant ethical issues being relevant to and embedded in the IAM.

Students then proposed alternative formulations of global utility that featured either spatial disaggregation, or that were based on per capita utility rather than globally aggregate utility. For example, they suggested that African utility (and consumption) might be optimized separately from, or weighted equally with that of North America. This spatial disaggregation was viewed as particularly important given that damages of climate change may be borne primarily by poorer populations who also benefit relatively little from the fossil fuel consumption that causes the damages.

The students clearly felt that the choice of optimizing globally aggregated utility was a strong ethical assumption that was open to alternative formulations, and proposed alternative formulations of global utility that featured either spatial disaggregation, or that were based on per capita utility rather than globally aggregate utility. For example, they suggested that African utility (and consumption) might be optimized separately from, or weighted equally with that of North America. This spatial disaggregation was viewed as particularly important given that damages of climate change may be borne primarily by poorer populations who also benefit relatively little from the fossil fuel consumption that causes the damages.

Students also suggested alternatives to the discount rate, ρ, used in these IAMs. In this case alternative values (value of wealth today vs. in the future) could be evaluated with different values of this parameter.

The students were not asked to judge whether or not given value judgments implicit in the IAMs were correct or incorrect. In fact, they were advised to identify ethical choices by identifying elements of the governing equations that they could not say were correct or incorrect without making a value judgment. Since the students had spent the entire semester to that point evaluating our evolving understanding of the physical and biological aspects of the carbon cycle, understanding that is proven right or wrong over time via hypothesis and hypothesis-testing, it was quite easy for them to identify elements of the IAM equations that could not readily be tested in this way.

Finally, in response to the third question the students considered whether or not the concept of "ethical uncertainty" was valid in the context of a climate IAMs, in parallel to the "factual uncertainty" which had been a topic of study for them throughout the semester. Ethical uncertainty is the idea that we might not be certain which is the correct or preferred ethical framework (Lockhart 2000). In this case, it would imply that a "correct" climate IAM cannot be defined without first defining a set of values necessary to guide the equations governing the IAM. The students were clearly convinced that strong ethical assumptions were embedded in the IAMs reviewed in the class. They noted that alternative value choices could be quantified by altering the structure of the core equations, the values of the parameters in these equations, or the constraints chosen to be applied to the optimization problem. Students also concluded that quantitative research into the impact of ethical assumptions on climate IAMs was a topic worthy of further research. For our purposes, we would underscore that graduate students in science were capable of identifying and discussing intrinsic ethics, that this was accomplished without extensive prior training in philosophy or ethics, and that the class was led and the module designed by an instructor whose research expertise was not in philosophy or ethics.

In reflecting on how the module was received by the students, however, we recognized that a natural next step in the pedagogical process would be to provide the students with a descriptive typology for identifying the various ways in which ethics can be embedded in research and analysis choices. Section IV is designed to provide such a typology by introducing and building upon research on values in science. While not claiming that this typology is fully comprehensive, it should provide students and instructors in the sciences with places to begin identifying intrinsic ethical issues in their own research.[8]

4. Intrinsic Ethics in Scientific Research

Our goal in discussing the climate IAM module was to outline a pedagogical approach to teach science graduate students to recognize that values and ethical issues can be embedded in scientific research. The climate IAM module represents an example in which the intrinsic ethical issues are relatively transparent, allowing for a pedagogical approach in which the instructor elicits identification of salient ethical issues from the students.

While the ethical issues embedded in scientific research may not always be as transparent as in the case of IAM,[9] the study of science by philosophers, anthropologists, and historians has demonstrated that values frequently influence and shape the research process in ways that have ethical import (Laudan 1977; Longino 1983; Longino 1983; Laudan 1984; Goggin and Blanpied 1986; Longino 1990; Harding 1991; Lansing 1991; Pickering 1992; Restivo 1994; Shadish and Fuller 1994; Margolis and Pickering 1995; Hess and Taylor 1996; Longino 1997; Giere 1999; Kitcher 2001; Woodhouse, Hess et al. 2002). Theorists have identified two sources of values in the production of scientific research, namely constitutive and contextual values (Longino 1983). The area of research ethics we label *intrinsic* ethics can be further clarified through this distinction.

According to Longino (1983; 1990; 1997) a number of constitutive values are embedded in scientific practice through a series of epistemic values. These include beliefs and practices concerning accuracy, precision, simplicity, norms of theoretical coherence, predictive power, generality of scope, and the like which are "the source of the rules determining what constitutes acceptable scientific practice or scientific method" (Longino 1990). Contextual values, on the other hand, are those individual or cultural values and interests that impact the direction of scientific research. Contextual values can determine which questions are asked or ignored about a given phenomena, or even which phenomena are the subject of research. They can affect what is seen as relevant data and how data is interpreted. They can also be part of the background assumptions that permit specific inferences or even determine the character of research in an entire field (Longino 1990). Furthermore, Longino (1990) argues constitutive and contextual values interact in ways that often result in ethical issues being embedded in scientific research.

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[8] We also hope this typology will be the beginning of additional reflection on the role of intrinsic ethics by philosophers of science and science studies theorists.

[9] There are many significant areas where intrinsic ethics may not have as apparent a link to or impact on society, as is the case in addressing climate change issues. For example, the choice of dose-response curves for toxicity studies can lead to conclusions that are false in significant ways, such as assuming a progressively higher dose causes higher risk. Where in fact, low exposure to some chemicals can be as problematic as high exposure, but medium exposure shows little problem. What is significant about an analysis of intrinsic ethics, in addition to forcing a questioning of assumptions, is that it requires one to also consider whether what is left absent in a scientific or engineering description of a system has consequences. For example, in the case of airbag manufacturers, air bags were engineered to prevent an unbelted 180-pound man from major injury or death in a head-on collision. Yet, what was left absent in the initial analysis was what such a powerful airbag safety system could do to a 100-pound woman or a 45-pound child.

The pedagogical approach we describe in this paper and label *intrinsic ethics* is based on the insight that the interaction of constitutive and contextual values can result in values and assumptions having ethical import being embedded in scientific research practice. While this insight helps to explain *why* intrinsic ethics is an important component of scientific research ethics, it does not offer tools to render these issues more transparent. To accomplish this, in Section 4.1 we present and build upon a classification of such interactions.

4.1 Typology of intrinsic ethics

While the distinction between constitutive and contextual values is productive, Anderson (2009) catalogues ways in which contextual and constitutive values interact provides a helpful typology of ways ethical issues get embedded in scientific research practice that can a be helpful pedagogical tool for identifying instances of intrinsic ethics.

Anderson (2009) offers six categories in which contextual values may be of influence, noting that whether their influence is epistemically harmful or helpful is an open question that would require additional analysis in a case-by-case process.

1. *Selection and weighting of cognitive values*. Specific cognitive values such as simplicity, scope, internal consistency, consistency with other beliefs (conservatism), and empirical adequacy that are appealed to by scientists to bridge the gap between theory and evidence can be selected or weighted based on contextual values.
2. *Standards of proof and handling of uncertainty*. Standards of proof often incorporate social values. As Anderson writes, "Social scientists reject the null hypothesis (that observed results in a statistical study reflect mere chance variation in the sample) only for P-values < 5%, an arbitrary level of statistical significance. Bayesians and others argue that the level of statistical significance should vary, depending on the relative costs of type I error (believing something false) and type II error (failing to believe something true). In medicine, clinical trials are routinely stopped and results accepted as genuine notwithstanding much higher P-values, if the results are dramatic enough and the estimated costs to patients of not acting on them are considered high enough" (Anderson 2009).
3. *Classification.* The ways observed phenomena are classified or interpreted may be influenced by contextual values. Anderson illustrates that the distinction, for example, "between health and disease reflects moral judgments about human welfare and appropriate ways of dealing with problems, as well as judgments about causation" (Anderson 2009). Further, the selection of empirical data as relevant to a study is also relevant to this category,
4. *Methods.* Choice of methods for either data collection and/or analysis reflects the context of the researcher and impact significantly the epistemological framework of the research. "The methods selected for investigating phenomena depend on the questions one asks and the kinds of knowledge one seeks, both of which may reflect the social interests of the investigator" (Anderson 2009).
5. *Causal Explanations; Explanations of Meaning; Narratives*. Causal explanations produce a conception as to what is happening within a given model or analysis. However, many simplifications and reductions are made just to make a model usable, and in doing so, there is no guarantee that a significant causal relationship does not go

either unseen or unconsidered. "For most phenomena, the number of factors that have a causal impact on their occurrence is vast—too large to comprehend or test in a single model. Investigators must therefore select a subset of causal factors to include in the models they test. This selection may be based on considerations of cost or availability—some types of data are hard or expensive to get; cheap and accessible methods may be better suited to testing the causal influence of some variables than others. The selection of causal variables may also be based on fit with the social or personal interests of the investigator (Longino 1990; 2001) These interests often reflect background social and moral judgments of blame, responsibility, and acceptability of change" (Anderson 2009).

6. *Framework or Global Assumptions*. The interests of the research are reflected in accepting certain framework conditions, such as the representational limits of an analysis, or in choosing the values of certain variables, within a model, as being "more" representative of reality than a different variable. "Longino (Longino 1990) and Tiles (1987) argue that the selection of framework assumptions may depend on their fit with the interests of the inquirer" (Anderson 2009).

We would add to the catalogue one additional category:

7. *The Choice of Research Questions.* Research results are epistemologically impacted by the scope and range of research questions. When contextual values impact problem choice, whether due to individual interests, funding agency interests, or broader societal interests, contextual values become interwoven into research practice. Further, choice of research question can also influence whether or not certain risks are taken into account, or are able to even be considered within the framework of a given research program. (See, e.g., Schrader-Frachette 1985)

Given these various venues in which constitutive and contextual values can arise in the context of scientific research, we contend that the inclusion of intrinsic ethics within research ethics pedagogy is an essential component of any adequate approach to research ethics in the sciences. It is only in this way that scientists and the scientific community can cultivate critical reflection about the norms that they are embracing and examine the ethical issues inherent in their research.

4.2 Intrinsic Ethics Typology Applied to Climate IAM Case

While the intrinsic ethics component of the climate change management IAM analysis was sufficiently transparent for students to identify instances without prior training in the above discussed categories, in this section, we apply the typology to this case to further illuminate aspects of intrinsic ethics. Application of the typology is done here to both demonstrate that there are more intrinsic ethics in the IAM case than those presented above, and to provide example as how the typology can be used to generate intrinsic analyses and further content for pedagogical use.

The *selection of cognitive values* (#1) is applicable, in this case, in the assumption that the models are meaningful and relevant to decision-making even though they are simplistic (Edwards 1999; Miller 2001). For example, in using globally average utility (*U*), the models do not distinguish between situations where consumption is distributed evenly from situations where people in some regions consume a lot (are very wealthy) while others consume little (are very poor), as long as the average consumption in these situations is the same. Another instance is in accepting the universality of defining utility (*U*) globally, as opposed to defining it according to a series of aggregated local considerations. Hence the models are considered useful for decision-making even though they oversimplify their projections. Another issue is whether the discounted utilitarianism ethical framework (Equation 1 above) is an adequate or appropriate framework for climate change policy (Funtowicz and Ravetz 1994; Risbey and Kandlikar 1996; Baum 2007).

Along a similar line of reasoning as *selection of cognitive values (#1),* issues concerning *standards of proof and handling of uncertainty (#2),* become apparent when considering whether a particular climate impact scenario is probable enough to take into account in optimal growth analysis. For example, if the probability for a certain catastrophic climate impact to occur would be below one percent, should it be considered part of the IAM? What may be considered as "statistically" insignificant in a scientific domain may be considered very important in a policy analysis.

Issues of *classification* (#3) arise in the selection of certain thresholds as relevant, such as the inclusion of the MOC collapse constraint in the McInerny and Keller (2008). Here the authors classify this phenomenon as a limit to what is acceptable (not violating the MOC threshold) and what is either beyond the ability of consumption and utility (Equation 2) to define ("priceless") or is a loss of discounted utility that is too great to allow ("utterly catastrophic"). The models represent these damages via a *damage function,* which describes the relationship between climatic phenomena and decreases in the discounted utility optimization criterion (Equation 1 above). Different value judgments will in general lead to different ways of classifying climatic phenomena in the models. Other thresholds also can apply (cf. Keller et al, 2008), for example, students noted that preservation of the natural system for its own sake is a constraint that could be added to a climate IAM if this was chosen to be of value. Further, the *selection of certain values for variables* also produces value constraints, such as in the choice of the elasticity parameter (α), which how much a unit of consumption is worth depending (or not if α=0) on whether you are richer or poorer.

Choice of *methods* (#4) presents intrinsic issues in both decisions of how to define certain model parameters and in the decision to approach climate policy analysis through computer modeling in the first place. A noteworthy methodological decision in model parameterization occurs when little empirical information exists for certain parameters. Here modelers might develop parameter value estimates by consulting with researchers with expertise on these parameters (as in Nordhaus 1994), in which case issues arise in which experts are selected, what questions are asked, how the questions are asked, and how multiple experts' responses for a given parameter are aggregated into a single parameter value. Alternatively, modelers might simply offer their best guess for the parameter value, in which case issues arise in what the what the modeler considers to be a good guess. Finally, the decision to approach climate policy analysis with computer modeling methods raises issues of whether models suggest more precision in results than is warranted and whether results might be biased by model structures (Funtowicz and Ravetz 1994; Risbey and Kandlikar 1996; Baum 2007).

Issues of *causal explanations, explanations of meaning, and narratives (#5)* are found, for example, in how climate change IAMs define consumption and utility and in the types of policy recommendations coming from the analyses. Utility is defined strictly in terms of per capita consumption. This definition supports a narrative in which per capita consumption is viewed as a good thing. Meanwhile, others have questioned the appropriateness of these cultures, including given the challenges posed by climate change (c.f. Sayer 2009).

Both analyses also reflect *framework assumptions*, (#6) namely, the assumption that optimal climate management strategy is determined by optimizing the discounted sum of utility (U), possibly with certain constraints, and assumptions about the effectiveness and applicability of a carbon emissions tax. Further *framework or global assumptions* are found throughout the choices of modeling schemes and model parameter values. These choices include the choice to use the RKC model, choices of discounting parameters, damage function specifications as discussed above.

The choice of research questions (#7) can, for example, determine the climate change IAMs focus on optimal emissions reductions and carbon tax rates instead of other aspects of climate change policy. This focus means that other policy approaches may get neglected. One other approach is smart growth city planning. As Baum (2007) elaborates, smart growth city planning can be an effective climate change policy according to the ethics of the climate change IAMs. However, the models overlook this type of policy because the modeling research chooses to focus on questions of optimal emissions reductions and carbon tax rates.

While not all intrinsic issues will be found in all cases, the application of the intrinsic typology here demonstrates how these seven issues can be identified within various steps that take place in along the construction of a given economic growth optimization analysis. As this case demonstrates, intrinsic ethics are deeply and widely embedded in climate IAMs, and as ethical issues, they need to be made apparent and engaged as an integral part of the research design process.

5. Research Conclusions

Our study provided empirical support for the following research findings:

A. Institutional implications of the intrinsic ethics approach to research ethics pedagogy

As universities respond to the America COMPETES Act[10] which requires that all undergraduate and graduate students, as well as postdoctoral researchers that are funded by NSF grants be provided "appropriate training and oversight in the responsible and ethical conduct of research,"

[10] Passed in August, 2007, the America Creating Opportunities to Meaningfully Provide Excellence in Technology, Education, and Science Act (America COMPETES), was designed to ensure competitive investments by the United States in science and engineering research and in science, technology, engineering, and mathematics (STEM) education. The Act focuses on a) increasing research investment; b) strengthening educational opportunities in science, technology, engineering, and mathematics from elementary through graduate school; and 3) developing an innovative infrastructure.

we argue that it is essential that they base the content of this training on a comprehensive model of research ethics that includes intrinsic ethics. As we illustrated in our overview of the climate IAM case study, the intrinsic approach requires both knowledge of the relevant scientific theories and practices as well as ethical analysis. Unfortunately, this approach to ethics is not commonplace in either ethics or science programs, nor have methods for teaching the intrinsic approach been fully developed.

To address this deficit in intrinsic ethics education, we propose a case study based approach to developing pedagogical content for both instructors and graduate students, an example of which was given in this essay. Our experience established that the process of case/module development was effective both in eliciting ethical discussions and considerations with students and in deeply engaging participating science faculty in the production of ethical content of their own research area for use by their students . We also offer the above-described typology as an additional pedagogical technique for identifying and analyzing intrinsic ethical issues in the sciences.

We further conclude that in order to deepen the engagement between science and ethics and include intrinsic ethics into research ethics pedagogy will require collaborative efforts between scientists and ethicists that should be supported through introducing institutional measures such as:

1. Teaching intrinsic ethics in the classroom: The approach to research ethics involving primarily non-classroom training is not sufficient to provide future scientists the skills they need to identify ethical issues embedded in their research. We thus urge that intrinsic ethics be included within regular graduate science classes. Case studies of intrinsic ethics arising from the scientific content of the course gives students the clear message that research ethics is not simply an issue of compliance with a set of rules, but a skill they need to cultivate to ensure fully responsible conduct of research.

2. Scientists lead the inquiry: Our case studies were developed by science faculty based on class content. While RCR specialists and ethicists can readily develop pedagogy for teaching traditional RCR content and provide pedagogical resources for scientists as they develop case study analyses of intrinsic ethical issues relevant to their classes, our experience demonstrates that intrinsic ethical issues are best identified and articulated by scientists who have a deep familiarity with the issues and assumptions embedded in a given analytical framework since such ethical issues are grounded in the methods and operational terms of a given scientific practice.

3. Collaboration between scientists and ethicists: We are well aware that scientists are not currently trained to be attentive to ethical issues embedded in scientific practice. Thus, unless the scientist happens to also to have training in ethics, we further conclude that collaboration with ethicists and/or science studies theorists[11] is essential to fully articulate the intrinsic ethics of a scientific problem. To develop pedagogy for teaching intrinsic ethics in the sciences, scientists would lead the identification of key issues which they think have ethical ramifications in

[11] For the purposes of this paper we use this phrase to refer to those who study science from a variety of disciplinary and interdisciplinary perspective including philosophy, anthropology, history, and sociology of science as well as science, technology, and society theorists.

dialogue with theorists who are sensitive to how best to fully identify and articulate embedded ethical issues in the sciences.

B. Intrinsic ethics will take time and greater collaboration between ethicists and scientists, but will likely lead to new research paths

What became readily apparent over the duration of the collaboration is that the development of an intrinsic approach to teaching research ethics requires an investment of significant time to build the foundation for productive collaboration. The team met regularly during the three year tenure of the grant and in that time developed the knowledge and skills needed to effectively work as a team. The result of a successful collaboration, however, is that it creates the foundation for new research.

6. Conclusions

As has been demonstrated here, both in theory and through an in-depth examination of approaches to climate *integrated assessment models*, ethics and values are embedded in the construction of scientific research design and outcomes. We have referred to these kinds of ethical issues as intrinsic ethics as opposed to procedural and extrinsic ethics, which represent two additional ethical dimensions of scientific research. While we acknowledge the degree and manner in which ethics and values are embedded within research are varied and context dependent, we contend that instances of intrinsic ethics, nonetheless, can be identified and appreciated through the typology and analytical approach offered here. These provide pedagogical tools that can be used to detect and examine intrinsic ethics across multiple research contexts in the sciences.

Finally, we have illustrated that there are a number of advantages to the intrinsic approach to research ethics we have put forward in the case study and typology, particularly when it is a component of the broader EDSR Program. These advantages are that the intrinsic approach: a) is grounded in practical problems scientists face when conducting research and thus the approach is empirical and applied; b) with proper training, it is a form of ethical analysis that can be performed by scientists while conducting scientific research and analyses; c) that science faculty members can be trained to effectively teach intrinsic ethics in their classes; and d) that attention to intrinsic ethics can, at least in some cases, lead to new research programs. Further, taking these advantages into account, we see significant potential for further investigations into the applicability of this approach to support the goals of science policy programs, such as the America COMPETES Act of 2007.

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